CARBONIFEROUS FOSSILS FROM THE KUTTUNG ROCKS OF NEW SOUTH WALES

by K. S. W. CAMPBELL

ABSTRACT. Brachiopod, polyzoan, molluscan, conulariid, and blastoid faunas from the Booral and Isaacs Formations on the south-eastern side of the Gloucester trough, north of Newcastle, N.S.W., are described. Five new brachiopod genera are established—the spiriferoids *Alispirifer*, *Liriplica*, and *Spinuliplica*; the rhynchonelloid *Lissella*; and the terebratuloid *Booralia*. Twenty new species and one new subspecies are named and described, including the type species of all the new genera. The faunas are not closely related to either the lower Carboniferous or the Permian faunas of eastern Australia, but there are affinities with those of similar age in Argentina. It is concluded that the Booral Formation is Westphalian in age and the Isaacs Formation possibly as late as Stephanian.

INTRODUCTION

THE fossils in the Booral Formation were discovered by Osborne and M'Coy in 1946, and a collection of the bryozoans was described by Crockford (1946). Crockford stated that the fauna came from the Upper Kuttung Series, about 2,000 feet from its top. Osborne (1950, p. 13) confirmed the Upper Kuttung assignment, adding that he considered the fossiliferous strata of the Booral and Limeburner's Creek districts to be 'coeval with freshwater glacial silts and tillites'.

The bryozoans were recognized as being very similar to those of the Neerkol Group of the Rockhampton area and rocks of similar age near Mt. Barney in Queensland. Since most workers at that time agreed in dating the Neerkol Series as Moscovian, the Booral fauna was given a similar age from the commencement of investigations. Hence assuming the accuracy of these correlations, it became possible for the first time to date the early part of the Kuttung glaciation on marine fossil evidence.

In order to check the position of the fossiliferous horizon in the stratigraphic succession the area has been mapped in more detail than previously, and the results of this work are being published elsewhere. Further fossil localities in the Booral Formation have been discovered, as well as a new marine fossil horizon in the Isaacs Formation, and a plant-bearing horizon in the Karuah Formation. A short paper describing one member of the fauna, the trilobite *Australosutura gardneri* (Mitchell), which also occurs in Argentina, has already been published (Amos, Campbell, and Goldring 1960).

Stratigraphy. Osborne (1950) included the Booral horizon in his Upper Kuttung Series, but he gave no information on detailed correlations. His reason for this dating is the correlation of the thick toscanite unit some 1,700 feet below the fossiliferous beds with the Mt. Gilmore toscanite-dellenite development of the Paterson area, where it marks the top of the Lower Kuttung Series (Osborne 1950, p. 290). There is little doubt that these rocks are all the result of one more or less contemporaneous and very widespread volcanic episode, and there is no reason at the moment to doubt Osborne's correlation.

The upper volcanic rocks of the Booral area (Gloucester Volcanics) were considered (1950, p. 292) to be 'high up in the Glacial Stage', being equivalent to the Paterson Toscanites. This correlation is the result of the equation of volcanic rocks despite their

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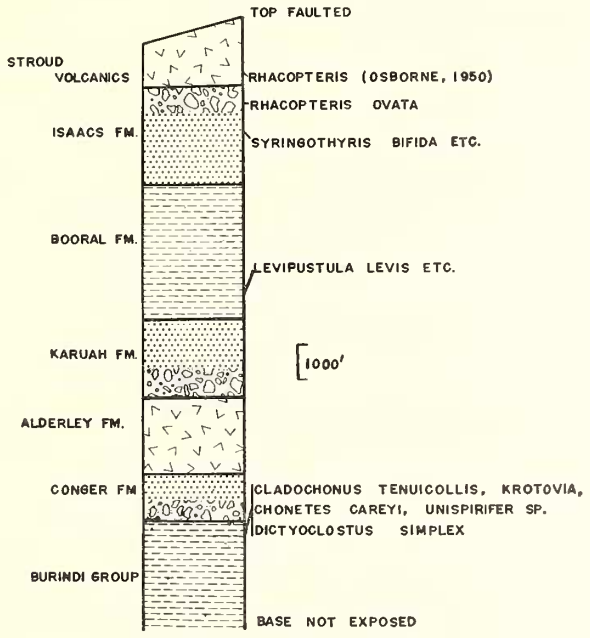
very different character in the two areas, those at Paterson being exclusively toscanite, while those at Booral are mainly rhyolites and basalts. However, at the present stage no more satisfactory scheme can be offered, and Osborne's suggestion is accepted tentatively.

On this basis, then, the Booral, Isaacs, and Karuah Formations are all equivalents of the Main Clastic Zone of Osborne's Glacial Stage (Osborne 1927), or the Mt. Johnstone Beds of Sussmilch and David (1919). It was in this unit at Glenoak, near Paterson in the Hunter Valley, that Osborne found rocks which he considered to be varves.



TEXT-FIG. 1. Stratigraphic column of the Carboniferous rocks in the Booral area.

It should be noted, however, that no evidence of glacigene rocks has yet been found in any of these three formations in the Booral–Stroud area, and that the glacial rocks containing marine microfossil debris mentioned by Osborne (1950, p. 25) are not physically continuous with the rocks of this area, the powerful Allworth fault being interposed.

Age and relationships of the faunas. In these faunas there is a total of twenty-three genera. At the present time four of these (*Spinuliplica*, *Liriplica*, *Booralia*, and *Lissella*) are known only from eastern Australia, and three from eastern Australia and Argentine (*Levipustula*, *Alispirifer*, and *Australosutura*). This is a particularly high percentage of 'Gondwana' types, especially when it is considered that the remaining sixteen genera include the broadly conceived *Rhombopora*, *Fenestella*, *Polypora*, and *Sanguinolites*.

In relation to the Lower Carboniferous faunas of the continent, these faunas present a revolutionary aspect. Only nine genera are known to be held in common, *Phricodothyris*, *Alispirifer*, *Syringothyris*, *Fenestella*, *Polypora*, *Fistulamina*, *Sanguinolites*, *Posidonia*, and *Cypricardinia*. The number of genera persisting through to the Permian in the

area is unknown, but it is unlikely to be more than eight. Included in these are *Fenestella*, *Polypora*, *Composita*, *Sanguinolites*, and *Limipecten*.

The age of the fauna is difficult to determine. The *Levipustula* faunas are well known in Queensland where they overlie coralline limestones dated as Upper Viséan (Hill 1934), by an interval of approximately 1,000 feet (W. Fleming, pers. comm.). Whitehouse (unpubl.) and Maxwell (1951) have both considered the Neerkol Group in which *Levipustula* occurs to be of Moscovian age, the main evidence being the similarity

TABLE I

Section of Fossiliferous Rocks east of Booral

The fossiliferous unit varies considerably in thickness along the strike, and the section below has been taken through its thickest part, near 019840. Only the most prominent fossils in each unit are listed.

TOP

1. Barren Sandstone.
2. Band of crinoidal siltstone containing *Liriplica alta* and *Booralia ovata*. Thickness 2 feet.
3. Dense black siltstone with abundant crinoid columnals and containing richly fossiliferous lenses with *Alispirifer lamellosus*, *Spinulicosta spinulosa*, *Levipustula levis*, *Fistulamina frondescens*, *Fenestella spp.*, and *Polypora spp.* Thickness 30 feet.
4. Dense black mudstones, in places silicified, but with few fossils. Thickness 50 feet.
5. Mudstone crowded with *Levipustula levis*. Thickness 10 feet +.
6. Grey to black mudstone with abundant smaller fossils including *Spinuliplica spinulosa*, *Lissella booralensis*, *Composita magnicarina*, *Fistulamina frondescens*, *Fenestella spp.*, and *Polypora spp.* Thickness 30 feet.
7. Hard, grey to black siltstone, with quantities of comminuted carbonaceous material, and containing *Alispirifer lamellosus*, *Spinuliplica spinulosa*, *Phricodothyris booralensis*, *Composita magnicarina*, *Levipustula levis*, *Fistulamina frondescens*, *Fenestella spp.*, *Limipecten flexiauriculus*, and *Calloconularia minima*. Thickness 25 feet.
8. Black mudstones with *Fistulamina frondescens* and crinoid columnals. Thickness 10 feet.
9. Barren coarse sandy beds.

between the associated *Spiriferellina neerkolensis* and *Neospirifer pristinus* and certain American Pennsylvanian species.

Outside Australia *Levipustula* is known from the Westphalian B and basal Westphalian C of the Franco-Belgian coalfield and Britain, and from an unknown horizon in the Karaulakh Mts. of Russia, as mentioned by Maxwell (1951). Our species are most similar to *Pustula rimberti* Waterlot, of the lower Westphalian C.

Although the genus *Limipecten* is known from Viséan rocks in Britain, it does not become abundant or widespread throughout the world until middle Westphalian times, as for example in the Des Moines Series of North America. At least three species of this genus are known to be associated with the *Levipustula* faunas in New South Wales, suggesting that they are not older than Middle Westphalian.

Lissochonetes has not yet been found in the Booral Formation, but farther east at Bombah Point on the Myall Lakes it is found with an *Alispirifer-Levipustula* fauna. This genus is not known anywhere in the world earlier than the base of the Pennsylvanian.

Alispirifer has been found by Mr. B. A. Engel (pers. comm.) in association with *Marginirugus* on horizons much lower than the Booral Formation, and probably as low as the early Viséan. However, in Argentina, Amos (1958) has recorded two species of

'*Spirifer*', which probably belong to *Alispirifer*, from the upper part of the Tepuel System, the tentative age of which he considers to be Moscovian.

Information available at the present time is that *Calloconularia* is restricted to rocks of Pennsylvanian age, and though the data are admittedly incomplete, it remains as some support for a post-Viséan age for the Booral fauna.

The occurrence of *Syringothyris* in the Isaacs Formation may be construed as evidence in favour of an earlier age in the same way as Harrington (1938) used *S. keideli* as an indication of a Lower Carboniferous age for the San Juan tillites of Argentina. However, syrinx-bearing syringothyrinoids are known to occur as high as the Agglomeratic Slate in Kashmir (*S. lydekkeri*), and Amos (1958) has found a species related to *S. keideli* in the Upper Tepuel System (see above).

Both developments of marine fossils lie beneath beds containing a rich *Rhacopteris* flora. In the past, so far as Australian geologists have been concerned, this genus has been considered to be a Lower Carboniferous index (Walkom 1944). However, in South America it is known to range up into the Itararé Group of Pennsylvanian age, where it is associated with rocks of glacial origin (Caster 1952). Under similar climatic conditions there seems to be no reason why it should not have a similar range in Australia.

All the positive evidence supports an age not older than Pennsylvanian for the Booral fauna, while the evidence of *Levipustula* and *Limipecten* favours Middle Westphalian. The negative evidence, e.g. the absence of any distinctive lower Carboniferous genera, also favours this interpretation. The fauna of the Isaacs Formation is possibly as young as the Stephanian.

SYSTEMATIC DESCRIPTIONS

Order CONULARIIDA Miller and Gurley 1896
Suborder CONULARIINA Miller and Gurley 1896
Family CONULARIIDAE Walcott 1886
Subfamily PARACONULARIINAE Sinclair 1952
Genus CALLOCONULARIA Sinclair 1952

Type species *Calloconularia strimplei* Sinclair, Upper Pennsylvanian of Oklahoma.

Remarks. See Moore and Harrington (1956, p. 65).

Calloconularia minima sp. nov.

Holotype. F.4123A; paratypes F.4123B–G; from the Booral Formation below the main *Levipustula* bed, near 019840.

Description. Faces of equal width; unknown whether transverse section square or rhombic; apical angle ranges from 20° to 26°; corners with well-formed furrows; shell somewhat thickened in corners; transverse ribs narrow, rather closely spaced, and much narrower than interspaces; measurements of number of ribs on mid-face of three specimens at given distances from the apex are:

	Specimen 1			*Specimen 2*	*Specimen 3*		
Distance from apex in mm.	15	25	35	*c.* 45	10	15	20
Number of ribs per 3 mm.	9	6	5	3	12	10	7

transverse ribs slightly deflected adorally in corner angles, and those of adjacent faces

alternate; on mid-face a distinct ridge across which ribs show an even curvature, or more frequently sub-angular flexure; ribs both continuous and alternate, sometimes showing both conditions on one face; very fine cross-bars, often not visible on adapical portions of test, between ribs; they number about five per mm. at a distance of *c.* 30 mm. from apex; internal moulds also with extremely fine cross-bars at same spacing; at adoral end of internal moulds, crests of infillings of transverse ribs show very fine shallow incisions, indicating thickening of test in this position; apex and aperture not observed.

Remarks. I am in doubt as to whether this species should be referred to as *Paraconularia* or *Calloconularia*. Moore and Harrington (p. 65) give as a generic character of *Paraconularia* 'mid-line on faces indicated only by slight deflection of ribs along it'. In my specimens there is a distinct ridge along the mid-faces, and hence they would appear to be excluded from that genus. Despite the above statement, however, the figures of *Paraconularia* given by these authors include many in which the mid-line is marked by alternating transverse ribs. No details of the mid-face of *Calloconularia* are given.

Class BLASTOIDEA
Genus PENTREMITES Say 1820

? *Pentremites sp.*

Plate 56, fig. 2

Material. F.4714c, from the beds below the main *Levipustula* bed, near 019840.

Description. A single radial plate, length about three times width; ambulacral area *c.* 0·5 of total plate length, narrow, and with narrow, sharp, everted margins; triangular area below ambulacrum separated off from remainder of plate by its slightly greater arching, and by the abrupt change in direction of growth lines at its margins; profile of basal edge almost straight; upper edges not observed; ornament of growth-lines only.

Remarks. The upper part of this plate is badly broken and so the proportions given above are only estimates. The contour and outline indicate that the basals also must have been elongate and hence that the vault/pelvis ratio was low—probably slightly less than 0·5—and that the pelvic angle was correspondingly low. The form of the whole calyx must have been similar to that of the more elongate representatives of *Pentremites okawensis* Weller.

Its Carboniferous age together with the morphological data suggest that the specimen could be placed in any one of the genera *Pentremites* Say, *Orophocrinus* von Seebach, or *Metablastus* Etheridge and Carpenter.

Suborder PRODUCTOIDEA Maillieux 1940
Superfamily PRODUCTACEA Waagen 1883
Family OVERTONIIDAE Muir-Wood and Cooper 1960
Subfamily OVERTONIINAE Muir-Wood and Cooper 1960
Genus LEVIPUSTULA Maxwell 1951

Type species *L. levis* Maxwell, Neerkol series of Queensland.

Diagnosis. See Muir-Wood and Cooper 1960.

Remarks. The spine bases do not appear to be divisible into the three groups as suggested by the above authors. There is no independent row along the hinge, but there are several rows set obliquely to the hinge in many specimens. On others the auricular spines are irregularly arranged. The arrangement of the spines on the body of the pedicle valve is irregular to quincuncial. There are also fine spines on the brachial valve.

There is a close comparison between *Levipustula* and the forms referred by Waterlot (1932) to *Productus* (*Pustula*) *piscariae* and *P.* (*P.*) *rimberti* from the Westphalian of northern France. One possible point of distinction is a slight sinus in some specimens of *P. rimberti* but this is not a constant character, and in fact may be due to slight distortion of the specimens. Demanet (1943) referred Belgian Westphalian forms to both of the above species, and these show the long upright spines on the ears, the trifid dorsal face of the cardinal process, and the non-dendritic adductor muscle scars in the brachial valve (Demanet pers. comm.). Whereas Waterlot records that in his specimens of *P. rimberti* the spines are developed from the middle of the spine bases, Demanet informs me that in his specimens they are given off from the anterior extremity as they usually are in *Levipustula*. Both the French species occur in Britain and I have examined numerous specimens in the Geological Survey and Museum.

Levipustula levis Maxwell

Plate 56, figs. 18–30

1951 *Levipustula levis* Maxwell, p. 11, pl. 2, figs. 4–13.

Material. Many hundreds of specimens from all levels in the fossiliferous part of the Booral Formation.

Remarks. Specimens from both mudstone and sandstone are available and show some differences, chiefly in the density of the spines. The following comments are intended only as a supplement to already published descriptions.

Body of pedicle valve ornamented with very fine concentric growth-lines together with occasional minor rugae; spine arrangement varies from quincuncial to irregular; decrease in spine density on trail common; occasional specimens with irregular bands of spines on trail, or with very elongate spine bases; on body of valve spines invariably developed from front end of spine bases, which vary greatly in length even over small areas of shell, adjacent individuals on one specimen are 2 mm. and 6 mm.; average length of bases 3 mm.; auricular spines on circular bases, stand out at high angle to shell, and often arranged in a roughly linear pattern of three to five rows directed anterolaterally from the hinge at angles of 10°–20°; occasionally irregularly arranged; size of auricular spines increases away from umbo.

Brachial valve with gently concave visceral disk and narrow geniculate margins; umbo very small (*c.* 0·5 mm.) and convex; ornament of short oval depressions and fine spines; depressions very variably developed in size and number, and may occur over whole valve or be restricted to anterior and lateral portions; spines much finer than those of pedicle valve, usually absent within 5 mm. of umbo, and less frequent on trail than body of valve; spines arise directly from shell or from very short bases, and directed at a high angle to the shell surface.

Pedicle interior often with a thickening just forward of the hinge and running inside the flanks.

Ventral surface of cardinal process either gently rounded or with a shallow medium

groove; ventral tip of process slightly bifid, and its dorsal surface deeply trilobed, the central lobe in some specimens bearing a very fine shallow depression; cardinal ridges strong and usually terminate before reaching cardinal extremities, but occasionally continue down the lateral margins for 5–10 mm.; adductor scars on subtriangular platforms which usually extend beyond anterior edge of scars themselves; brachial ridges rarely seen, but arise from antero-lateral edge of muscle platform, run antero-laterally and then swing round in a broad loop with the distal tip deflected in towards the septum.

Suborder SPIRIFEROIDEA Allan 1940
Superfamily SPIRIFERACEA Waagen 1883
Family SPIRIFERIDAE King 1846
Subfamily ACROSPIRIFERINAE Termier and Termier 1949
Genus ALISPIRIFER gen. nov.

Type species *A. laminosus* sp. nov., Booral Formation.

Diagnosis. Alate spiriferoids; hinge-line less than maximum shell width at early growth stages but becoming mucronate in adolescence and adulthood; pedicle cardinal area of moderate height, concave, with blunt terminations, and bearing numerous denticle grooves; sinus simple except for a very weak median plication which is not invariably developed; lateral slopes usually with eight to twelve simple rounded plicae, but very occasionally a plica bifurcates; the most lateral plicae very weak and often slightly sinuous; surface of both valves crossed by closely spaced regular concentric growth-lines and irregular growth halts, and by very fine radial lirae; lirae number about fifteen per mm., and are in line on adjacent lamellae; umbonal cavities of pedicle valve obliterated by shell thickening; dental lamellae almost completely involved in the thickening; distinctively rounded callus between the posterior edges of the dental lamellae and obstructing the posterior half of the delthyrium; small callus immediately beneath the brachial umbo carries the platy cardinal process; sockets small; brachial myophragm very weak where it joins the umbonal callus, but may thicken between the central pair of adductors; postero-lateral pair of adductor scars on the furrows bordering the fold and extending back to the umbonal callus.

Remarks. Two other genera are closely comparable with *Alispirifer*—the Devonian *Acrospirifer* Wedekind and the Permian *Pterospirifer* Dunbar.

In Greenland specimens of *Pterospirifer* the delthyrium is 'overarched by a high delthyrial covering that looks like a deltidium. Its surface sculpture is not sufficiently well preserved in the specimens seen to indicate it is a true deltidium or a symphytium' (Dunbar 1955). King (1850) described an English specimen referred to the type species, in which the delthyrium is almost completely arched over by a single strongly lamellose plate. I have been able to confirm this on several Magnesian Limestone specimens in the Sedgwick Museum and in the Geological Survey and Museum. Nothing comparable occurs in *Alispirifer*.

In the German *Pterospirifer alatus* there are sixteen to twenty plicae on each side of the sinus (Malzahn 1937, p. 38). On the Greenland specimens, Dunbar records the presence of 'a dozen or more rounded plications . . .', and in the British specimens there are twelve to sixteen. Bifurcation is a fairly frequent phenomenon. In *Alispirifer* there are fewer

than a dozen plicae, and bifurcation is rare. The sinus in *Pterospirifer* from all localities is from three to five times the width of the bordering plicae. In *Alispirifer* the sinus is relatively much narrower.

The internal structures of *P. alatus* are not well known. Dunbar records that the posterior part of the pedicle valve is 'considerably thickened by later shell growth', but no figures are given. The English specimens also are thickened across the shoulders but the extent of the thickening is not comparable with that of *Alispirifer*, in which the delthyrial cavity forms a pronounced finger-like extension. The brachial valves of these specimens show the presence of 'septa' supporting the crural plates, but such structures do not occur in *Alispirifer*.

Acrospirifer is of Lower and Middle Devonian age, and I can find no record of it in Upper Devonian or Lower Carboniferous rocks. At the present stage of our palaeontological knowledge, however, it would not be safe to place much weight on this apparent temporal discontinuity. The morphological similarities between the two genera are striking, and the differences slight. The chief points of distinction are: (1) There is no delthyrial callus in *Acrospirifer*. (2) The brachial myophragm of *Acrospirifer* develops as a rather broad triangular structure from the thickening in the notothyrial cavity, whereas in *Alispirifer*, although it is sometimes in contact with the notothyrial callus, it does not derive from that structure, and its posterior extremity is invariably fine and low. (3) There appears to be some doubt as to the structure of the radial ornament of *Acrospirifer*. Mailleux (1936) has described specimens of the type species, *A. primaevus* (Steininger) in which there are fine radial lirae which do not appear to be interrupted by the concentric 'striae'. These observations have been confirmed for the same specimens by Allan (1947, p. 448). Solle (1953, p. 29) in his diagnosis of the genus makes no mention of radial lirae, but speaks only of growth laminae and papillae arranged in rows. Fine surface sculpture may therefore prove to be a point of distinction from *Alispirifer*. (4) The delthyrium in *Acrospirifer* is partly covered by a simple, highly arched plate. (5) The notothyrial cavity in *Acrospirifer* is usually only slightly thickened, and the cardinal process is not on a large boss.

Alispirifer is widespread in the post-Lower Burindi rocks of New South Wales, and is represented by several species. It probably occurs in Argentine also.

Alispirifer laminosus sp. nov.

Plate 55, figs. 17–23

Holotype. F.4938; paratypes F.4940–F.4945 from beds above and below the main *Levipustula* bed, near 019841.

Description. Shell very transverse and the extremities almost invariably mucronate; in most specimens mucronation slight, but in others long slender mucros developed, the largest (relatively) observed being about 10 mm. long on a specimen 75 mm. in total width; cardinal area proportionately wide and only slightly concave, except immediately beneath the umbo, where the concavity is greatly increased; cardinal ridges very angular; considered as a whole, area slightly apsacline—almost orthocline; well-developed slightly irregular denticle grooves over entire surface of cardinal area; cardinal area tapers towards the cardinal extremities, where it is abruptly terminated; margins of delthyrium clearly defined by narrow dental ridges; delthyrial angle averages 50°–55°;

sinus narrow (sinal angle averages 23°), and either simple or bearing faint median elevation or flattening, scarcely prominent enough to warrant the term plication; lateral slopes simply plicate, no plication observed to bifurcate and no intercalation; nine to twelve rounded plicae on each side of the sinus in adults, the most lateral ones tending to become quite irregular; plicae approximately of same size as interspaces, the latter being slightly more angular than the former; whole surface (excluding the cardinal area) covered by regular closely set growth lines, and irregularly spaced lamellae which tend to become more regular towards the front of the shell; very fine radial lirae (about 15 per mm.) cover the surface; lirae appear to be in line on adjacent lamellae, and occasionally run continuously across successive lamellae, causing slight serration in their edges.

Brachial valve much less convex than the pedicle; cardinal area well developed, slightly concave, almost parallel sided, and anacline; median fold narrow, rounded on top or gently flattened.

Umbonal cavities of pedicle valve almost entirely filled with callus; postero-dorsal part of the delthyrial cavity occupied by a callus with a rounded dorsal surface which usually projects very slightly through the delthyrium beyond the plane of the cardinal area; margins of delthyrium not obscured by this callus since its edges unite with the inner faces of the dental lamellae on the inner side of the edges of the delthyrium; posterior half of the delthyrium usually obstructed by callus; muscle field in adults almost as wide as long, but in juveniles relatively narrower; muscle field folded by the plicae which border sinus; second lateral pair of plicae sometimes visible on outer edges of field, but always much reduced; adductor scars indefinite and very variable in outline; diductors scars usually longitudinally striated; genital pits distributed across the shoulders for half the width of the shell and for 4 or 5 mm. forward of the muscle field.

Cardinal process on face of well-developed callus situated between sockets; sockets themselves unusually small for a shell of this size, but socket plates quite thick; crural plates small, do not reach to the floor, and not supported on adminicula; posterior end of adductor scars project into small cavity dorsal to umbonal callus; in adults posterior edge of the central pair of muscle scars approximately 5 mm. forward of the edge of umbonal callus; length of central scars *c.* 8 mm.; lateral scars occupy the plication bordering the fold, but may extend sideways on to first lateral plica near their rear extremity; myophragm touches the callus, increases slightly in size between the central adductors, and dies out at their anterior extremity.

Remarks. The denticle grooves on the cardinal area of the pedicle valve vary very considerably in depth. Since all the specimens are preserved as moulds, it is possible that differential solution of the denticle traces took place before the consolidation of the enclosing sediment (Young 1884), and that the varying depth of the grooves is the result of differing degrees of solution.

In most specimens the adductor scars of the pedicle valve are situated in a shallow furrow and extend the whole length of the muscle field. In others they are restricted to the anterior two-thirds of the field. In outline they vary from parallel sided to canoe shaped. The myophragm varies from a small notch at their posterior edge, to a fine ridge extending over almost their entire length.

Both '*Spirifer*' *chubutensis* and '*Spirifer*' *sp.*, which Amos (1958) has described from the upper part of the Tepuel System of Argentina, are to be referred to this genus, but the preservation of the material is too poor to warrant specific comparison.

The species is common throughout the Booral Formation and occurs on all levels.

Alispirifer laminosus undatus subsp. nov.

Plate 63, figs. 3–4

Holotype. F.4765; paratypes F.4756–F.4764, Isaacs Formation near 987823.

Description. This subspecies differs from the parent species in the irregular, wavy form of many of its plicae, and in the bifurcation of occasional plicae. Neither of these features is present on all specimens, nor even on most. Also, the callus within the delthyrium of *A. laminosus* is usually much stronger than in *A. l. undatus*, and the denticle grooves on the cardinal area of its pedicle valve are slightly more widely spaced and more irregular.

Remarks. This subspecies is distinguishable only on a population basis, as there is a considerable overlap in all features with the parent species.

Subfamily PHRICODOTHYRINAE Caster 1939
Genus PHRICODOTHYRIS George 1932

Remarks. This genus was reviewed by me in 1955. Since that date two new species have been described from New South Wales by Cvancara, and there is other additional information from specimens from several new localities and horizons.

The spines of *P. immensa* each consist of a pair of incomplete tubes, a split being present along the edge facing the shell. Though no actual spines of other species have been observed, the structure of the spine bases (Cvancara 1958, pl. 111, figs. 25–26) clearly suggests that they also were split in the same way. George (1932, p. 528) figures the spines of *Phricodothyris* as complete tubes, and the spine bases as completely enclosed.

None of the N.S.W. species has small pustules between and in front of the spine bases as do *P. monopustulosa* Demanet and *P. tripustulosa* Demanet, and some undescribed British species.

No transverse barbs have been observed on the few spines of *P. immensa* available.

George (p. 527) comments that 'the development of spines (in *Phricodothyris*) on successive lamellae is not, other than exceptionally, in radial linear series'. On most of our species the arrangement of the spines is frequently, though not invariably, radial. Both radial and non-radial sectors sometimes occur on the one shell.

These features, coupled with the invariable development of strong dental lamellae, ventral adminicula, and median septa, may yet require the removal of the New South Wales species from *Phricodothyris* and their inclusion in *Kitakamithyris*. However, more details of the spines of *Kitakamithyris*, and of the occurrence of double-barrelled spines on species with a '*Reticularia*'-like shell form in western Europe, are required before definite conclusions can be reached.

The internal radial ornament common to the whole group of reticulate spiriferids has never been described in detail, and its function remains unknown. Several features which need explanation have been observed in our specimens. Increase in the number of radial

ribs takes place both by bifurcation and implantation. Some ribs are very short and impersistent. Others after bifurcating reunite. On the pedicle valve, at least, ribs are present on the inner surface of the palintrope. On well-preserved specimens ribs are never developed around the margins. It is fairly certain, therefore, that they are not deposited at the mantle edge but are the result of later deposition by the inner surface of the mantle. They are not obliterated on the older parts of the shell by the filling up of the intervening furrows, but they are almost always partly preserved on the muscle fields.

hey can scarcely be related to the pallial system because of their general disposition and their presence inside the palintrope where no pallial sinuses are present. They cannot be related to the presence of strong mantle setae (i.e. setal tracks) because they are not mantle edge phenomena, and obviously there can be no setae along the hinge. Their origin remains obscure.

Phricodothyris booralensis Campbell

Plate 54, figs. 1–3

1955 *Phricodothyris booralensis* Campbell, p. 381, pl. 18, figs. 18, 19.

Neotype. F.4903A from the Booral Formation near 019840.

Remarks. The types of this species were destroyed in a fire at the University of New England in February 1958. The above neotype has been selected from several topotypes which have since come to hand. From these specimens it has been possible to add the following details to the original description.

Pedicle umbo prominent (not small as previously thought probable); cardinal area high, and bearing shallow denticle grooves numbering five to seven per mm.; dental ridges prominent; hinge line about four-fifths of the maximum shell width; ventral adminicula slightly divergent to subparallel along the floor of the valve, and extending approximately one-quarter of its length; dental lamellae strong; median septum reaches maximum height (between 1 and 2 mm.) near its posterior extremity and maintains it over almost its entire length; in transverse section median septum usually broad at base and with a much narrower capping lamella, but some specimens show a simply triangular section; on the inner face of each dental lamella are a pair of low ridges increasing in strength towards the umbo; external pair unite on the umbo, and internal pair coalesce to form a pronounced flange restricting the apex of the delthyrium.

Crural plates large, thick, strongly concave on their inner (notothyrial) faces, and fusing with the floor of the valve for a short distance in front of the cardinal process leaving small umbonal cavities; socket plates thick; sockets very small; cardinal process concave, formed of up to about forty plates in available specimens; thick smooth callus forward of cardinal process produced into a gradually diminishing myophragm; adductor scars large and ovoid, but poorly defined.

Fine radial ribbing on interior of both valves, ribs numbering two to three per mm.

Phricodothyris immensa sp. nov.

Plate 54, figs. 4–11, and Plate 59, fig. 5

Holotype. F.4917C; paratypes F.4914G, F.4915A–D, F.4916B, F.4917B, F.4918–F.4919, from the Isaacs Formation at 987823.

Description. Shell very large for genus; hinge-line only slightly shorter than maximum width of shell, and cardinal extremities subangular to rounded; pedicle valve more strongly convex than brachial, particularly in umbonal regions; pedicle umbo high and moderately incurved over a concave cardinal area; fine irregular ridges, many of which bifurcate towards cardinal ridges, on pedicle cardinal area; eight to ten ridges per 5 mm. along the hinge; no hinge denticles observed; delthyrium wide and open (delthyrial angle *c.* 45°); no delthyrial covering plates present; narrow (sinal angle 18–25°), shallow, median sinus extends from umbo; concentric ornament regular, with lamellae spaced eight to ten per 10 mm. medially; this spacing uniform at all except final adult stages, where crowding always occurs; lamellae quite distinct but frequently not very sharply defined; eight to eleven spine bases per 5 mm. medially, at all growth stages; spine bases all clearly divided into two, the bifid portion usually occupying slightly more than half the length of each lamella; pointed posterior portion of scar, so common in members of this group, very rarely visible, and where present is on posterior half of lamella; no pustules between major spine bases.

Brachial valve more or less oval in outline; low rounded fold extending from umbo, and bordered on either side by narrow and slightly flattened strips; commissure uniplicate; specimens with cardinal area 5 mm. high common; notothyrium very broad, (notothyrial angle 80–90°); cardinal area ridged after same fashion as that of pedicle valve.

Dental lamellae strong and supported on thick adminicula; thickening of dental lamellae, particularly on their outer faces, common, and their inner faces often bear one or two strong longitudinal ridges; adminicula run either a straight course along floor of valve, or are slightly concave toward each other; angle of divergence along floor of valve is about 25°; from their anterior ends run very low rounded ridges which converge towards the mid-point of the valve, and bound the canoe-shaped muscle field; in the apex of delthyrial cavity is a small callus from which develops a median septum of variable height (2 mm. maximum) extending whole length of muscle field; adductor and diductor scars indistinguishable; inside upper half of delthyrium is a narrow thickened plate arching over beneath the umbo, and formed from two thickened ridges on inner faces of dental lamellae; in occasional specimens this plate united with median septum for a short distance; whole of inner surface covered with radial ornament typical of reticulate spiriferids, but unusually coarse and deep, there being six to ten ridges per 5 mm. on median portion of lateral slopes; size of these ridges diminished on muscle field, particularly around its margins.

Crural plates long and deep, and concave on their inner faces; crural plates welded to floor of valve for a short distance, but never supported by adminicula; at apex of slightly thickened region between bases of crural plates is large striated cardinal process, formed of from twenty-five to forty-five separate plates, median one of which often slightly larger than others; from edge of sessile portions of crural plates arise low rounded ridges which diverge slightly forwards and then arch around to meet at a point one-half to two-thirds of the length of the valve, thus isolating a very large, ovate muscle field; not possible to differentiate two pairs of adductors except at the posterior margins, where short thickened projections from umbonal thickening divide off the central pair; very low myophragm runs length of field; sockets straight, not enclosed at apex, and socket plates not thickened; descending lamellae and spires robust; individuals of moderate size with about twenty volutions in spire.

Remarks. This species is obviously related to *P. booralensis* and at first the two were considered to be conspecific. However, *P. immensa* sp. nov. has (1) much coarser internal radial ornament—six to ten ridges per 5 mm. as opposed to ten to fifteen in *P. booralensis*; (2) coarser ornament on the cardinal areas of both valves; (3) broader muscle fields in both valves; (4) a stronger umbonal thickening in the brachial valve; (5) a more deeply impressed anterior part of the pedicle muscle fields; (6) heavier crural plates.

Superfamily PUNCTOSPIRACEA Cooper 1944
Family SPIRIFERINIDAE Davidson 1884
Subfamily SPIRIFERELLININAE Paeckelmann 1931
Genus LIRIPLICA gen. nov.

Type species *Liriplica alta* sp. nov., Booral Formation.

Diagnosis. Shells of medium size; both valves rather strongly convex; pedicle umbo high and incurved; lateral slopes curve around on to distinct but obtuse cardinal ridges; hinge-line less than maximum width of shell and cardinal extremities rounded at all growth stages; approximately six low, rounded, plicae on each lateral slope; median sinus two to three times wider than the bordering plicae, and carrying a low, rounded, median plica; fold distinct and bearing a median furrow on its anterior half; surface of both valves crossed by fine regular growth-lines and coarse irregularly spaced growth halts, and by very fine discontinuous radial lirae; umbonal cavities of pedicle valve obliterated by massive shell thickening which extends as far forward as the edges of the dental lamellae; strong callus in apex of delthyrium buttressed to inner faces of dental lamellae by thickened outgrowths; strong median septum; brachial valve thickened along hinge; crural plates curved inwards and meeting immediately beneath the umbo to support the flat, platy, cardinal process; central adductor scars restricted to crest and sides of the median fold; postero-lateral scars on bordering furrows and may encroach posteriorly on to the first lateral plicae; spires and jugum unknown; punctae irregularly arranged and numbering about ten to fifteen per sq. mm.; diameter of punctae in inner shell layer 0·015 to 0·04 mm.

TEXT-FIG. 2. Diagrammatic sections across two spines of *Pliricodothyris immensa* sp. nov. Reconstructed from moulds, F.4939A–B. ×75.

Remarks. This genus is similar externally to Reed's poorly known genus *Paraspiriferina*. The following points suggest that the two are distinct: the absence of a plica in the sinus of *Paraspiriferina*; the fact that Reed mentions nothing about fine surface ornament, apart from lamellation, when we know from his other descriptions that he was fully aware of the importance of such; and the fact that the records of similar Permian forms elsewhere in the world (e.g. *Spiriferina multiplicata* King, of Dunbar (1955) from Greenland) make no mention of either a much thickened pedicle umbo or lirate surface.

From *Spiriferellina* it is readily distinguished by its proportionately narrower sinus and fold, narrower more numerous plicae, median plica in the sinus, and lirate rather than spinose ornament. *Punctospirifer* also has sharper cardinal ridges, and differs further in the absence of fine regular growth-lines in addition to the growth lamellae, the absence of a plication in the sinus, the absence of strongly thickened umbonal

cavities in the pedicle valve, the lack of the strong convex thickening occupying most of the delthyrium, and the presence of a strongly protruding cardinal process.

I have not found species referable to this genus anywhere in the literature.

Liriplica alta sp. nov.

Plate 53, figs. 9–18

Holotype. F.4884; paratypes F.4885–F.4887, F.4891B, F.4892A–B, F.4893A–E, F.4894B, and F.4895G–L, from the uppermost fossiliferous bed near 019840.

Description. Shell approximately as long as wide; hinge-line less than the maximum shell width throughout ontogeny; cardinal extremities rounded; cardinal area high and strongly concave; umbo pointed; delthyrial angle averages 35°; narrow shallow sinus extends the length of the valve, and within it a distinct median plica reaches to within 1 cm. of the umbo; lateral slopes well rounded and curve around on to the distinct but obtuse cardinal ridges, which become progressively sharper towards the cardinal extremities; lateral slopes each carry six or seven well-rounded plications; surface of each valve crossed by very fine closely spaced growth-lines, and at irregular intervals by much larger growth halts; fine radial lirae numbering twelve to fifteen per mm. in the sinus, well developed over whole surface except cardinal areas; lirae not similar in size, the largest being twice the size of the smallest; on adjacent lamellae, lirae appear to be in line.

Brachial valve much less convex than the pedicle; rather evenly convex in longitudinal profile, and gently convex on the lateral slopes; fold evenly rounded on the posterior half of the shell but develops a shallow median furrow on the anterior half; cardinal ridges curved toward the umbo, but become straighter laterally; size and spacing of punctae as in the generic description.

Pedicle interior with excessively thickened umbo and umbonal cavities; thickening continued well forward inside cardinal area, and a thick rounded ridge protrudes slightly anterior to hinge; this ridge arises from the sides of the dental lamellae, and runs outward and slightly forward, petering out before reaching lateral margins of valve; dental lamellae very swollen on their inner surfaces and fill the delthyrial cavity to varying degrees; median septum high and blade-like, arising from the muscle field at a very sharp angle; septum 1–2 mm. in width at base, and extremely variable in transverse section; in juvenile specimens septum passes backwards into narrow rounded callus partly filling apex of delthyrium, but this continuity obstructed in adults due to merging of callus with inner swollen edges of dental lamellae; extent to which delthyrium obstructed by callus variable, but usually one-half to two-thirds of its length; muscle field long and narrow, width/length ratios ranging from 0·4 to 0·55; adductor scars apparently sometimes restricted to sides of septum, but often occupying flattened area along its margins as well; few coarse genital pits scattered within 5 mm. in front and at the side of muscle field; hinge line not denticulate.

Brachial valve much thickened across shoulders; sockets small and shallow, and open over their entire length; socket plates thick, and buttressed by shoulder thickening; crural plates short and not attached as septa to floor of valve, their dorsal edges being deflected inwards and becoming confluent immediately beneath the umbo, forming a shelf on which the cardinal process is developed; cardinal process concave on ventral face; central adductor scars short and situated well forward (*c.* 5 mm. long in valve

22 mm. long, and their posterior edge *c.* 8 mm. from tip of umbo); scars restricted to median fold, broadest *c.* 1–2 mm. from their anterior extremity and taper gently backwards; postero-lateral adductor scars often on narrow sharp ridge near front, becoming broader and flat toward rear, and usually reaching to within 1 mm. of edge of crural plates; rear edge of these scars sometimes encroaching on first lateral plica; myophragm present.

Remarks. The callus occupying the delthyrium is very distinctive. Its outer surface is well rounded, and is either simple or divides into two toward the hinge-line. Usually its surface is not protruded beyond the plane of the cardinal area, but occasionally it is. In external view it is sharply separated from the inner faces of the dental lamellae by deep angular grooves. The muscle field and septum of the pedicle valve are highly variable. In some individuals there is a clearly defined trough on either side of the septum, presumably for the attachment of the lateral parts of the adductors. In other specimens there is no sign of these. Some of the variations in the longitudinal profile of the septum are given in text-fig. 3.

I know of no species to which *L. alta* is related.

Genus SPINULIPLICA gen. nov.

Type species *Spinuliplica spinulosa* sp. nov., Booral Formation.

Diagnosis. Shells of medium size; hinge-line less than maximum shell width at all growth stages; umbo low to moderate in height; pedicle cardinal ridges distinct but obtuse; lateral slopes with six or seven well-rounded costae; median sinus much broader than the bordering costae, and carrying a low median plication; surface of both valves crossed by fine growth-lines and coarse irregularly spaced growth halts; closely spaced, fine, anteriorly directed spines cover whole surface; dental lamellae strong and diverging down margins of sinus; median septum massive; umbonal cavities only slightly thickened; crural plates strong and frequently uniting with wall of shell to form short septa; cardinal process deeply platy, and supported on a thickening between the crural plates; adductor scars of brachial valve as in *Liriplica*; punctae number twenty to forty per sq. mm. and are irregularly arranged; in inner shell layer diameter of punctae is 0·03 to 0·07 mm.

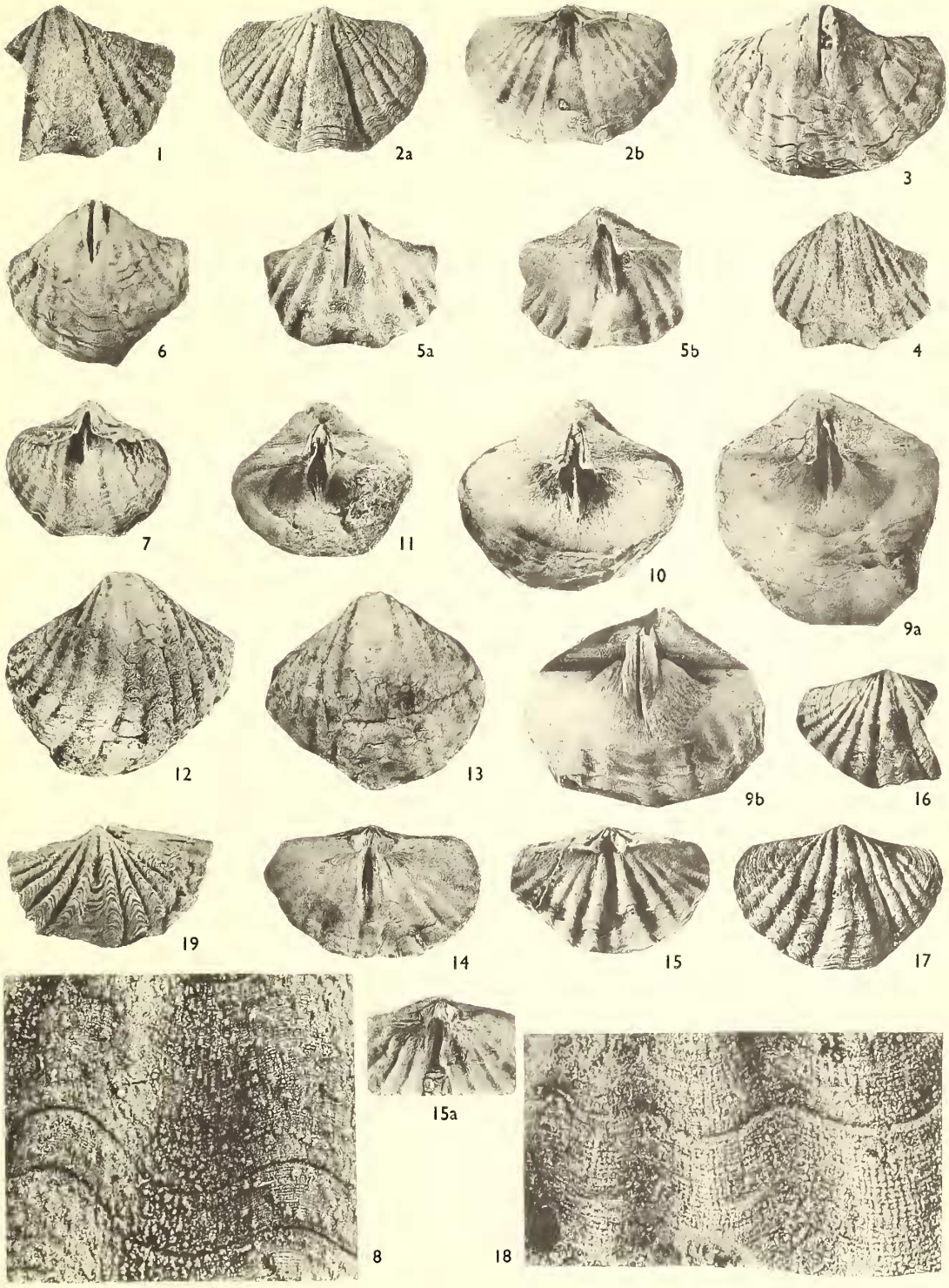
EXPLANATION OF PLATE 53

All figures natural size, and of rubber casts unless otherwise stated.

Figs. 1–8. *Spinuliplica spinulosa* sp. nov. 1, 4. Exteriors of pedicle valves, F.4934D, and F.4934A. 2*a–b*, Exterior and interior of brachial valve, F.4931. 3, Mould of interior of pedicle valve, F.4922, holotype. 5*a–b*, Mould and rubber cast of interior of pedicle valve, F.4934B. 6, Internal mould of pedicle valve, F.4925. 7, Interior of small pedicle valve, F.4928A. Cardinal area slightly depressed into the shell. 8, Detail of surface ornament, F.4932A, ×10.

Figs. 9–18. *Liriplica alta* sp. nov. 9*a–b*, Rubber cast and original internal mould of interior of pedicle valve, F.4885. 10–11, Interiors of two incomplete pedicle valves. Anterior parts of shell broken away. F.4893D and F.4894B. 12–13, Two pedicle valves F.4886 and F.4884. The latter is the holotype and is not a cast. 14–15*a*, Interiors of three brachial valves, F.4895G, F.4893B, and F.4887. 16–17, Brachial exteriors, F.4888B and the latter destroyed by fire. 18, External mould, showing details of ornament, F.4893J, ×10.

Fig. 19. *Punctospirifer sp.* Pedicle valve with umbo and part of brachial valve showing behind, F.4866.

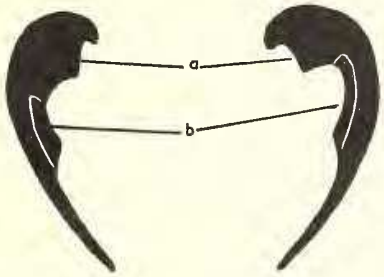


CAMPBELL, Carboniferous brachiopods

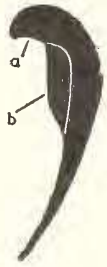
Remarks. The appearance of the crural plates as septa is probably to be correlated with the absence of thickening in the umbonal cavities of the brachial valve. Where the thickening is strongest the crural plates are buttressed by it and do not appear as septa.

The genus is distinguished from *Liriplica* by its lower pedicle umbo, much less thickened pedicle valve, no distinctive callus between the dental lamellae and obstructing the delthyrium, and the presence of spines rather than lirae on the surface. *Spiriferellina* is smaller in size, has proportionately larger plicae in relation to the fold and sinus, and different fine surface ornament. *Punctospirifer* differs in its more extended hinge, non-plicate, fold and sinus, much higher cardinal area, and its lirate rather than spinose surface ornament.

Spiriferellina neerkolensis Maxwell possibly belongs to this genus, though spines have never been described on its surface, and the number of lateral plicae is fewer than in the type species.



TEXT-FIG. 3. Longitudinal sections of the pedicle valve of *Liriplica alta* gen. et sp. nov. showing the form of the umbonal callus and the median septum, together with the shape of the delthyrial cavity. The anterior third of each shell is partly reconstructed. × 1. a, umbonal callus; b, median septum.



TEXT-FIG. 4. Longitudinal section of the pedicle valve of *Spinuliplica spinulosa* gen. et sp. nov. showing the form of the umbonal callus and the median septum, together with the shape of the delthyrial cavity. × 1. a, umbonal callus; b, median septum.

Spinuliplica spinulosa sp. nov.

Plate 53, figs. 1–8

Holotype. F.4922; paratypes F.4923–F.4928A from beds below the main *Levipustula* bed near 019840, and F.4934A–D from near 018859.

Description. Shell slightly wider than long at adult stage, and hinge-line less than maximum width of shell at all growth stages; young forms with rather well-rounded cardinal extremities, but adults show a slight tendency to become subrectangular; cardinal area of moderate height and strongly concave; sinus twice to three times width of bordering plicae, and contains a median plication which does not quite reach the umbo; on some specimens this plication fades away on anterior part of sinus, which then becomes flat bottomed; lateral slopes well rounded and carry six or seven well-rounded plicae separated by furrows of similar size and shape.

Brachial valve flatter than pedicle; umbo rather prominent; fold not very high and carries a distinct median furrow almost to umbo.

Surface of both valves crossed by very fine, delicate growth-lines and coarse irregularly

spaced growth halts, closer together towards front of shell; very fine, hollow, irregularly spaced spines cover surface, both on and between plicae, and in sinus; spines derived from anterior edges of elongate bases which gradually increase in height forwards; spine bases range up to 1 mm. in length, and adjacent ones about 0·1–0·4 mm. apart; spines probably no more than 2 mm. long.

Dental lamellae thick and supported on short thick wedge-shaped adminicula which diverge along margins of sinus; median septum very powerful, broadly based on floor of valve, and usually arises abruptly from diductor field, though sometimes with a gradual change of slope at its base; septum in transverse section irregularly triangular, though occasional specimens show a vertically walled lower portion capped by a triangular crest; maximum height of septum at a distance of 3–5 mm. from its anterior edge, towards which it then falls away on a concave slope; umbonal cavities relatively unthickened.

Crural plates thick, with their inner edges curved around and buried in callus supporting cardinal process; in some specimens crural plates unite with the outer wall of the valve to form septum-like structures; very weak myophragm; adductor scars as in *Liriplica*.

Remarks. There is some variation within this species at different localities within the formation. Particularly noticeable is the variation in the thickening of the pedicle umbo and the umbonal cavities, though even the most thickened individuals never approach the form of *Liriplica*.

The spines are preserved as moulds in mudstone and are pressed fairly closely to the shell. They are not completely tubular, but appear to be more or less cylindrical with a slit along the face adjacent to the shell. Some individuals appear to be tubular immediately adjacent to the shell wall but then split distally.

The species is widely distributed in both sandy and muddy facies, but has not been found in the *Liriplica* bed at the top of the fossiliferous section.

Genus PUNCTOSPIRIFER North 1920

Type species *P. scabricosta* North from the Lower Carboniferous of England.

? Punctospirifer sp.

Plate 53, fig. 19

Material. F.4866; from beds below the main *Levipustula* bed near 019840.

Description. Shell transverse, length about two-thirds width; cardinal extremities rounded in earliest stages, then acute, then mucronate, and finally acute again; pedicle umbo of moderate height, pointed and apparently only slightly incurved; sinus with a rounded to slightly flattened base; lateral slopes each with five strong rounded plicae, separated by sharp, subrounded interspaces; lamellae very strong and imbricating; fine radial lirae over whole surface.

Remarks. Only one specimen of this species has been found. It consists of an external mould of the pedicle valve and the internal mould of part of the corresponding brachial valve. The margins of the pedicle valve have been destroyed, but the form of the cardinal extremity has been preserved in the brachial valve. The external mould is covered with

small pustules which are, no doubt, the infillings of the punctae from the outside. Between these, and on the small areas where they are not developed, the surface is very delicately lirate.

I am referring this form to *Punctospirifer* because of its form and the details of its surface ornament. However, it differs from the type species in its fewer plications, and the relatively smaller sinus. Definite assignment to a genus is not possible without knowledge of the internal structures.

Subfamily SYRINGOTHYRINAE Schuchert and Le Vene 1929
Genus SYRINGOTHYRIS Winchell 1863

Type species *Syringothyris typa* Winchell, Lower Mississippian Burlington Limestone, Burlington, Iowa.

Remarks. There is some doubt as to the correctness of this generic assignment for the following reasons. (1) The sinus has furrows developed on its lateral parts. (2) The cardinal area of the pedicle valve appears to be vertically striated over its entire width. (3) The postero-lateral adductor scars are distinctly bifid. (4) The apical part of the syrinx is joined to the floor of the valve by a short 'euseptoid'. In this feature it resembles *Septosyringothyris* Vandercammen, but the other characters prevent it being placed in that genus.

?*Syringothyris bifida* sp. nov.

Plate 62, figs. 1–9, and Plate 63, fig. 5

Holotype. F.4917A; paratypes F.4909–F.4914A–E, F.4915E–G, and F.4916A, from the Isaacs Formation near 987823.

Description. Shell very transverse, being *c.* 1·75 times wider than long in adults though beyond a certain stage there is a marked allometric increase in length with respect to width; cardinal extremities subangular; apical angle varies from about 130° to 140°.

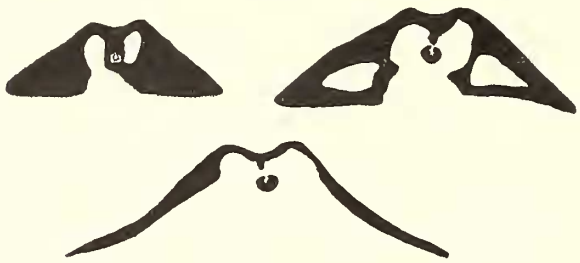
Length of cardinal area of pedicle valve between one-third and one-half of the total length of the shell; area gently and evenly concave over its entire length, in lateral profile forming a quadrant of a circle; delthyrial angle about 40°–45°; cardinal area appears to be vertically striated over its whole width, though the preservation is such that it is impossible to be certain of this; sinal angle from 16° to 35°; diverging from the margins of the sinus at a low angle are two shallow furrows which extend to the anterior margin, the first arising *c.* 5 mm. from the umbo and the second *c.* 10 mm.; lateral slopes with from sixteen to eighteen simple, low, rounded plicae, separated by furrows narrower and more angular than themselves.

Brachial valve only moderately convex; cardinal area 3–4 mm. high in valves 25 mm. long, and 5–6 mm. high in 45 mm.; fold high, with rather flat flanks, rounded crest posteriorly, and slightly furrowed medially over most of its length; lateral parts of flanks occasionally showing a single faint furrow.

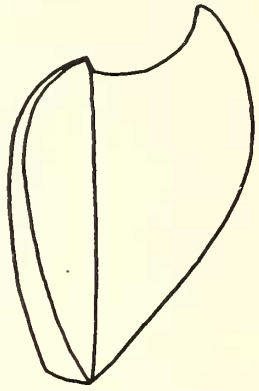
Surface of both valves, except for cardinal areas, covered with very fine elongate depressions, varying in length from 0·1–0·7 mm., and also varying in density; shell substance punctate, but density of punctae unknown.

Dental lamellae stout, but shallow, e.g. in specimens with cardinal areas *c.* 20 mm.

high, maximum depth of the dental lamellae (near their mid-length) is only *c.* 4 mm.; adminicula short, very strongly thickened, very widely divergent, and largely embraced in the extensive umbonal thickening; solid transverse plate closes only posterior third of delthyrium, in some cases a little more; outer surface of plate convex, and in most specimens with a low, rounded to angular, median ridge; well-developed syrinx with diameter of up to 6 mm. and length of up to 15 mm. measured from the tip of the umbo, though in most specimens diameter *c.* 3 mm. and length *c.* 10 mm.; syrinx projects well beyond edge of transverse plate, and split on its ventral face; inner surface of syrinx connected to floor of valve by a stout euseptoid; muscle field very large



TEXT-FIG. 5. Three sections across the pedicle umbo of *Syringothyris bifida* sp. nov. showing the relation of the syrinx to the septum. The specimen, F.4913, is partly in the form of a mould and the external surface of the shell has been reconstructed. The intervals are approximately 3 mm. and 2 mm. respectively. ×1.



TEXT-FIG. 6. Reconstructed lateral profile of *Syringothyris bifida* sp. nov. ×1.

and circumscribed by a low ridge increasing in height with age; adductor scars smooth, canoe-shaped in outline, and bounded by a very low, narrow, sharp ridge; posterior extremity of adductors situated *c.* 5–9 mm. in front of posterior edge of diductors, and their anterior extremity at or up to 3 mm. behind the edge of the field; broad diductor scars invariably exhibit a very delicate arrangement of ribbing, with pattern as follows: on anterior two-thirds ribs run anteriorly and antero-laterally, and on posterior third, separated by a sharp break in direction of ribs, they run laterally, or laterally towards the front and postero-laterally towards the rear; coarse genital pits on inside of cardinal area, beside muscle field, and occasionally forward of cardinal ridges.

Large callus immediately beneath the umbo of brachial valve bearing large deeply striate cardinal process 5–6 mm. broad and 2–3 mm. long in adults; crural plates broad and lying at a low angle to the general plane of the cardinal area, and with their posterior portions incorporated in the umbonal callus; ventral faces of crural plates slightly excavate and with their inner edges deflected ventrally; socket plates slightly thickened, and form a low rounded ridge where they attach to the shell wall forward of the hinge-line; no material preserving brachidia available; central pair of adductor scars situated with its posterior edge 15–20 mm. from umbo (measured around the curvature of the shell, in valves 40–50 mm. long), and scars themselves *c.* 23 mm. long; outline elongate oval, expanding slightly forwards, and situated on crest and flanks of fold; postero-lateral scars sharply bifid, reaching to within 3–7 mm. of anterior edge of

central pair, with their outer edges curving backwards in a broad arc, extending laterally on to the second costa lateral to the fold, and posteriorly to within 3–6 mm. of edge of umbonal callus; division in these scars 8–10 mm. from their posterior edges; straight inner segments run backwards along depressions bounding fold, and adjacent to central pair of scars; all scars slightly impressed, the degree of impression increasing posteriorly; very low myophragm flattens out into umbonal callus, or stops short of it; numerous fine, radial markings at anterior edge of fold.

Remarks. Sections from a testiferous specimen show structures very closely comparable with those figured by Amos (1957) for *Septosyringothyris* aff *keideli* Harrington both as regards the 'euseptoid' and the syrinx. In my internal moulds the 'euseptoid' varies considerably in strength, in some being virtually absent. This is no doubt due to the excessive deposition of callus around it. *S. bifida* differs in the form of the cardinal area of the pedicle valve, the more numerous lateral plicae, and the presence of furrows in the sinus. Amos (pers. comm.) informs me that his specimens are decorticated and that this may account for the apparent smoothness of the sinus. In 1958 the same author figured two poorly preserved specimens from the upper (Moscovian?) part of the Sistema de Tepuel as *S. keideli.*

The types of *S. keideli* compare very well with *S. bifida* in general form, size and disposition of the pedicle cardinal area and ornament. Further, Harrington has noted 'faint longitudinal rounded striae marking the surface of the sinus', in the only specimen in which the outer shell layers are preserved. The chief difference is the smaller number of plicae on the lateral slopes of *S. bifida.*

Specimens from the Moscovian part of the Agglomeratic Slate of Kashmir referred by Bion (1928) to *Syringothyris lydekkeri* (Diener) have a very similar form to this new species, and there is a similar arrangement of the dental lamellae and adminicula, but there appears to be no 'euseptoid' in the pedicle valve. Other critical details are wanting. It is interesting to notice that the pedicle cardinal area of the same species figured by Diener (1915, pl. 4, fig. 4) from the *Fenestella* Shales—a slightly earlier formation—seems to be vertically striated over its whole surface.

I can find no reference to comparable species from Europe or North America.

Superfamily ROSTROSPIRACEA Schuchert and Le Vene 1929
Family ATHYRIDAE Davidson 1884
Genus COMPOSITA Brown 1849

Type species *Spirifer ambiguus* Sowerby, Lower Carboniferous, England.

Remarks. This genus has been discussed previously by the author (1953, p. 15) in connexion with its differentiation from *Spirigerella* Waagen. As stated there, Grabau (1932) claims that *Spirigerella* has a large cardinal process which projects into the umbo of the pedicle valve, but no such structure is present in *Composita.* If this is a reliable basis for distinction, then the new species here described is clearly a *Composita* since no cardinal 'process' is developed at all, the diductor muscles being attached to the cardinal plate.

So far as I am aware this genus has not been recorded as such from the Carboniferous of eastern Australia, but Benson and Dun (1920) have referred specimens from the Tournaisian at Babbinboon to *Seminula subtilita* (Hall), which is a species of *Composita.*

However, these specimens appear to be incorrectly assigned. The incoming of this genus may prove to be a useful indicator in the Carboniferous of New South Wales and Queensland.

Composita magnicarina sp. nov.

Plate 55, figs. 1–8

Holotype. F.5276; paratypes F.5277–F.5278; from the Booral Formation near 018859.

Description. Shell of small to average size for the genus; width from two-thirds to four-fifths of the length; maximum width at two-thirds the length from the umbo; postero-lateral margins very gently curved to the point of maximum width and the anterior outline approaches a semicircular form; valves subequally convex.

Pedicle umbo gently incurved over its brachial counterpart, with its apex occupied by a small foramen *c*. 1·5 mm. in lateral diameter; foramen not complete but opens into the broad, open delthyrium; median sinus variable, ranging from virtually absent to a shallow rounded depression which originates variously at points between the middle of the valve and 2 to 3 mm. in front of the umbo; many specimens with only a mesial flattening; commissure only gently plicate, the fold being of the order of 2 to 4 mm. in height in adults; lateral slopes gently rounded.

Umbo of brachial valve high and acute and fits right into the delthyrium; valve either gently rounded or slightly flattened medially; surface of both valves crossed only by very fine, rather regular lines of growth.

Dental lamellae strong and reach one-third the total length of the valve, their inner surfaces distinctly concave and they thicken greatly towards the teeth; along floor of valve dental lamellae almost straight or only slightly divergent; almost whole floor of delthyrial cavity as far forward as anterior edge of dental lamellae occupied by a very finely concentrically striated pedicle muscle scar; adductor scars elongate cordate in outline and occupy one-half to two-thirds of total length, and one-third to one-half of total width, of muscle field; outer edges of diductor scars diverge slightly forwards for a little more than half their length and then converge to give a bluntly rounded anterior termination; posterior edges of diductor scars lie between tips of dental lamellae or just anterior to them.

Hinge-plate thick, its length from the umbo being one-fifth of the total length of the valve, and directed antero-ventrally; crural bases form low ridges just within the inner socket ridges; centre of plate forming a shallow trough with a low axial fold; apex of plate in juveniles with a small foramen which sometimes remains open and sometimes is closed by a callus in adults; largest foramen observed 1·7 mm. in length; diductor attachments a pair of slightly flattened areas one on each side of foramen; strong broad-based and sharp-crested median ridge arises just in front of umbonal opening, reaches its maximum height and width within 5 mm., and then usually tapers gradually to middle of valve; in some specimens, however, decrease in size not gradual but sharp, either where the septum enters the adductor field or where it reaches the rear end of the anterior pair of scars; median ridge never supports hinge-plate; adductor scars situated in a narrow shallow depression on either side of median ridge; posterior pair usually well impressed at rear edge which is situated 3 to 4 mm. from the tip of the umbo in adults, but it is usually very difficult to distinguish sharply between posterior and anterior pairs; when distinguishable, pairs are of about the same length; usually anterior

and posterior scars approximately equal in width, but sometimes posterior pair up to twice the width of the anterior, and sometimes anterior pair slightly the wider; front edge of muscle field tapers to an acute termination from which a pair of short pallial trunks is derived; posterior portion of valves sometimes with a few small, radially elongate genital pits; jugum not observed; about twelve volutions in each spire, the coiling being of the normal type for the genus (see Kozlowski 1914).

Remarks. This species occurs at almost all localities, and on several levels, in the Booral Formation. It is most abundant, however, on the lower horizons. The specimens from the finer sediments to the south of the highway are much larger in size and more variable internally than those from the type locality, and, in addition, they have some distinctive features. The dental lamellae are usually slightly longer, being somewhat more than one-third of the total length of the valve. The hinge-plate is usually more strongly thickened, and in some specimens it becomes ponderous. The median carina is often very broad and high and occasionally it supports the hinge-plate for a short distance beneath the umbo, but other specimens have exceptionally weak carinae. It is probable that the forms from the two types of sediment are phenotypic variants.

Composita sp.

Material. F.4979–F.4984 from the Isaacs Formation near 987823.

Remarks. These specimens are rather badly distorted, but sufficient details can be determined to separate them from *C. magnicarina*. They are more transverse in outline, have thinner shell material, and usually have a very weak median keel in the brachial valve.

Suborder TEREBRATULOIDEA Muir-Wood 1955
Superfamily TEREBRATULACEA Waagen 1883
Family DIELASMATIDAE Schuchert and Le Vene 1929
Subfamily? CRYPTONELLINAE Thomson 1926, emend. Cloud 1942
Genus BOORALIA gen. nov.

Type species *Booralia ovata* sp. nov. from the Booral Formation.

Diagnosis. Dielasmatids with ovate outline, and rectimarginate to slightly sinuate commissure; deltidial plates large and conjunct; cardinal 'process' flattened or more commonly bearing a globular median eminence; cardinal plate deeply concave and perforate; crural bases low; loop unknown; dental lamellae long; pedicle collar on dorsal side only, where it is buttressed against the deltidial plates by a short septum; foramen of moderate size, mesothyrid to submesothyrid; muscle scars of pedicle valve poorly defined, and adductor scars of brachial valve club-shaped; two pairs of divergent pallial trunks in each valve; punctae twenty to forty per sq. mm., and are *c.* 0·02–0·03 mm. in diameter in the inner shell layer.

Remarks. In the absence of any knowledge of the loop, it is difficult to know whether this genus is a cryptonellinid or a cranaeninid. From a stratigraphic point of view the latter appears to be the more likely, since members of that subfamily range up to the top of the Mississippian, whereas those of the former are probably restricted to the Devonian, though Cloud suggests that the Pennsylvanian *Cryptacanthia* may possibly

be a cryptonellid. However, from a morphological point of view *Booralia* seems to be closer to *Cryptonella* than *Cranaena* in its relatively long suberect to nearly straight beak, and its mesothyrid to submesothyrid attrite foramen. A further point of similarity is in the pattern of pallial trunks in the brachial valve. Cloud (1942, pl. 24, fig. 27) has figured pedicle and brachial interiors of a *Craenaena* or a *Hamburgia* which show the pallial pattern of the subfamily. In the brachial valve there appear to be four large straight trunks on either side of the mid-line. Cloud's description of the trunks in *Cryptonella* fits the pattern in *Booralia*.

Booralia is distinguished from all other members of both subfamilies by the presence of the long dorsally placed pedicle collar which is attached to the deltidial plates, and by the distant irregular spacing of the punctae.

Booralia ovata sp. nov.

Plate 55, figs. 9–16

Holotype. F.4892c; and paratypes F.4888–F.4891a, F.4893f–g, and F.4895g–l, from the *Liriplica* bed near 019840; paratypes F.4896–F.4901 from sandy bed near 018859.

Description. Pedicle valve moderately convex in longitudinal, and highly arched in anterior profile; outline elongate with umbonal angle between 80° and 90°; maximum width just forward of umbonal ridges; outline of anterior well rounded; umbo suberect to nearly straight; cardinal margin terebratulid; foramen of moderate size—*c*. 2 mm. across in specimens 30–40 mm. long—and mesothyrid to submesothyrid; foramen margin attrite; umbonal ridges subangular; surface smooth, without a sinus; commissure either rectimarginate or slightly sinuate; deltidial plates large and conjunct.

Brachial valve flatter than pedicle; umbo high and blunt; no fold; surface smooth.

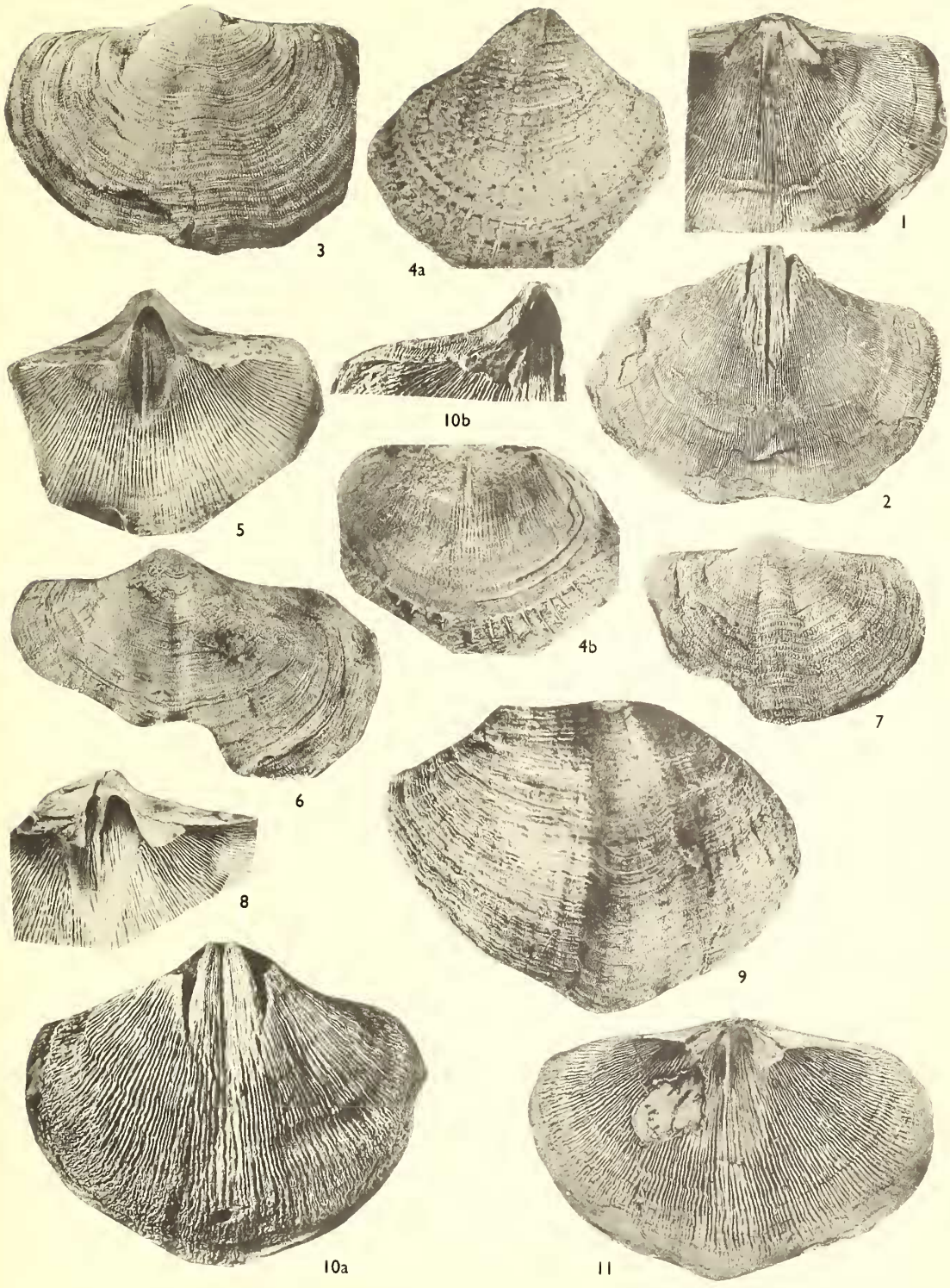
Dental lamellae strong, about one-third the length of the valve, strongly concave toward each other in transverse sections, straight along the floor of the valve or slightly incurved at their anterior tips; shell substance within delthyrial cavity slightly thickened, the anterior edge of the thickening forming a slight, arcuate ridge between the tips of the dental lamellae; pedicle adjustor scar in delthyrial cavity; adductor scars very poorly defined; relatively small lateral pair subovate and lying within strong pallial trunks diverging from the inner anterior edges of the dental lamellae; median pair of adductor scars not observed; lateral pallial trunks diverge from outside dental lamellae; pedicle collar developed on dorsal side only where it forms a sheath inside the delthyrium; collar and deltidial plates joined by a short septal plate.

EXPLANATION OF PLATE 54

All figures natural size, and of rubber casts unless otherwise stated.

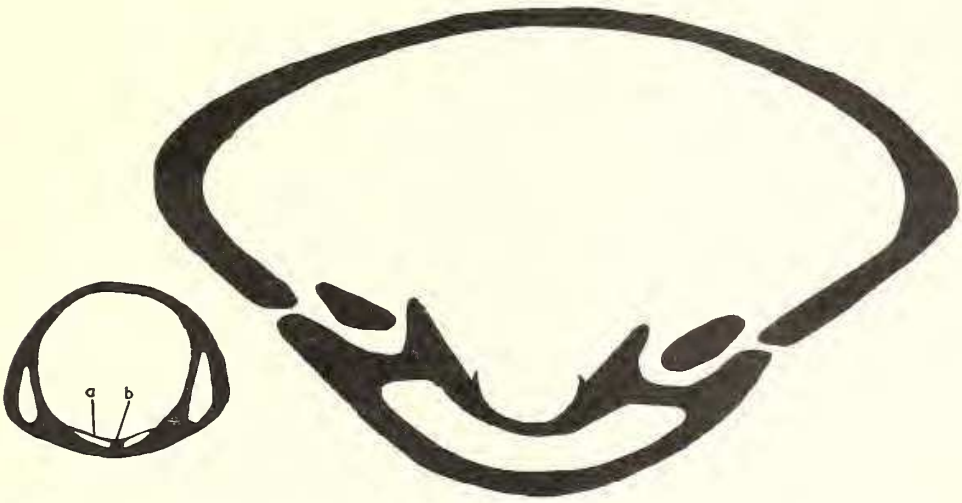
Figs. 1–3. *Phricodothyris booralensis* Campbell. 1, 3, Interior and exterior of brachial valve, F.4902a–b. 2, Internal mould of pedicle valve, F.4903a, neotype.

Figs. 4–11. *Phricodothyris immensa* sp. nov. 4*a–b*, Exterior and interior of pedicle valve, F.4939a–b, ×4·5, showing fringe of spines. 5, Interior of pedicle valve, F.4918. 6, Exterior of pedicle valve, F.4915b. 7, Exterior of small brachial valve, F.4914g. 8, Slightly oblique view of interior of posterior part of pedicle valve showing septum joined to ridges on inner faces of dental lamellae, F.4919. 9, Part of exterior of pedicle valve showing faint plication of surface, F.4914f. 10*a*, Internal mould of pedicle valve, destroyed by fire. 10*b*, Rubber cast of part of same showing denticle grooves on cardinal area. 11, Interior of brachial valve, F.4917c, holotype.



CAMPBELL, Carboniferous brachiopods

Cardinal plate short, free, perforate and deeply concave, its anterior edge concave forwards; crural bases distinct, sharp and running well back on to the plate; sockets large and socket plates short, very robust and joined to the outer wall of the shell by massive callus deposits making the posterior part of the shell very solid; myophores form flattened areas immediately forward of the umbo, or more frequently situated on a globular eminence sometimes of considerable size; two strong, broad, parallel



TEXT-FIG. 7. Two semi-diagrammatic sections across the umbonal region of *Booralia ovata* gen. et sp. nov., drawn from F.4901, an internal mould approximately 25 mm. long, the sections being taken 4 mm. apart. × 5. a, pedicle collar; b, septum joining pedicle collar to deltidial plates.

ridges, separated only by a narrow furrow, proceed from under the cardinal plate to a point about one-third the length of the valve from the umbo, and then diverge, making angles *c.* 25° with each other, presumably marking sites of pallial trunks; lateral trunks slightly concave towards mid-line, and diverging from central pair near edge of cardinal plate; adductor scars club-shaped, depressed, situated between median ridges and lateral pallial trunks, though usually partially encroaching on the former to a variable degree; lateral and central adductor scars not clearly differentiated; anterior edge of scars at or just on either side of separation of central pallial trunks.

Remarks. The specimens from the crinoidal bed (*Liriplica* bed) are large and have well-impressed internal structures, but most of them are fragmentary. Those from the sandy beds are very much smaller (? younger) and do not show the internal structures well, though they are sometimes preserved as complete internal and external moulds. I have considered the possibility that the two forms are distinct species, but for the present consider them to be phenotypic variants.

The cardinal process is a very variable structure. Almost all the large well-preserved specimens have the pronounced boss in the middle of the face of the cardinal process, but the smaller specimens from the sandy beds do not. However, there is no boss in one of the largest specimens, and so apparently age is not the controlling factor.

The median ridges on the posterior third of the brachial valve are clearly not pallial trunks, but the central pair of trunks is always derived from their anterior edges.

Suborder RHYNCHONELLOIDEA Moore 1952
Superfamily RHYNCHONELLACEA Schuchert 1896
Family CAMAROTOECHIIDAE Schuchert and Le Vene 1929
Genus LISSELLA gen. nov.

Type species *Lissella booralensis* sp. nov., Booral Formation.

Diagnosis. Small, impunctate rhynchonelliform shells with smooth umbones; lateral slopes developing a small number of rounded plicae toward the front of the shell; median sinus and fold well developed and carrying few plicae; dental lamellae fine and short; hinge-plate robust, with a distinct median ridge on its ventral surface, and strong flanges on its dorsal surface giving rise to the crurae; median septum high and long, but never supporting the hinge-plate at any stage; small perforation in hinge-plate immediately in front of umbo; muscle scars in the brachial valve complex, consisting of four distinct pairs; teeth and sockets not denticulate.

Remarks. This genus bears obvious resemblances to *Wellerella* Dunbar and Condra in its size, shape, ornament, dental lamellae, undivided hinge-plate with its ventral median ridge and its dorsally placed crural bases. However, according to Dunbar and Condra 'The apical part of the hinge-plate (of *Wellerella*) is supported by a very short simple median septum', whereas *Lissella* has a long, high septum which does not support the hinge-plate at any stage, and the hinge-plate has a small apical perforation. Certain species from the Permian ascribed by Stehli (1954) to *Wellerella* have in the brachial

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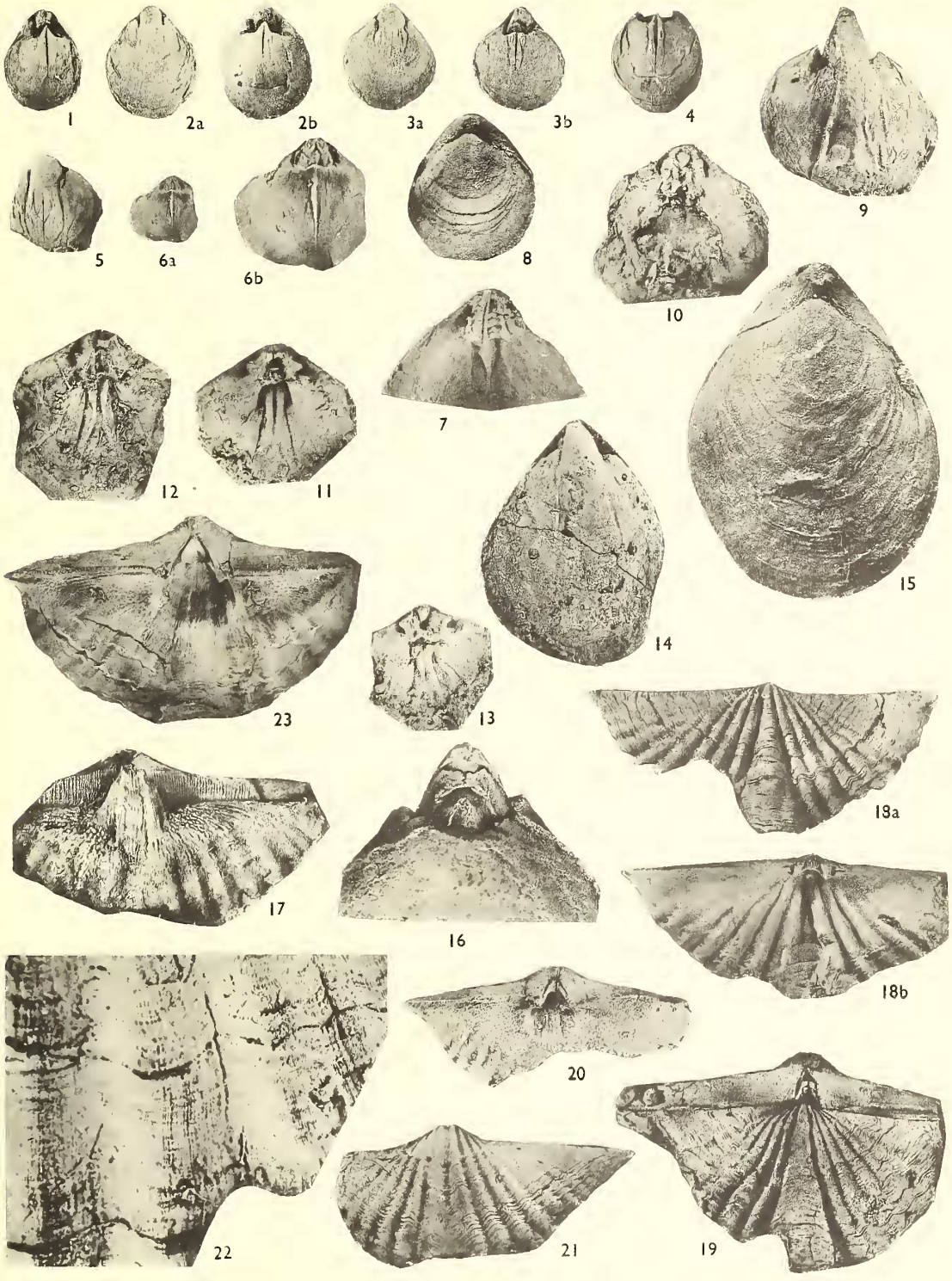
EXPLANATION OF PLATE 55

All figures are natural size unless otherwise stated.

Figs. 1–8. *Composita magnicarina* sp. nov. 1, Dorsal view of internal mould, F.5277. 2*a–b*, Ventral and dorsal views of internal mould, F.5278. 3*a–b*, Ventral and dorsal views of internal mould, F.5276, holotype. In 3*b*, the infilling of the brachial umbonal cavity has been cut away. 4, Brachial valve, internal mould, F.5300. 5, Umbonal part of internal mould of pedicle valve showing transversely striated umbonal cavity and adductor and diductor scars, F.5301. 6*a*, Rubber cast of interior of brachial valve showing hinge-plate and unusual myophores, F.5302. 6*b*, Same, ×2. 7, Rubber cast of interior of brachial valve showing hinge-plate and socket, F.5303, ×2. Slightly oblique view. 8, Rubber cast of exterior, showing foramen, F.4934F, ×2.

Figs. 9–16. *Booralia ovata* sp. nov. 9, Internal mould of pedicle valve with front part destroyed, F.4895A. 10–13, Rubber casts of interiors of umbonal parts of brachial valves, F.4893F, F.4889, F.4892C, and F.4895H. Note presence of boss on cardinal 'process' in all except fig. 11. 14, Internal mould of pedicle valve with infillings of umbonal cavities broken away, F.4888. 15, Dorsal view of rubber cast of exterior, F.4889B, ×1·7. 16, Dorsal view of internal mould with umbonal infilling cut away to expose cardinal 'process' and crural trough. Note crural base on left-hand side; strongly developed pedicle collar on dorsal side; and short septum connecting the pedicle collar to the deltidial plates, F.4898, ×2.

Figs. 17–23. *Alispirifer laminosus* sp. nov. 17, Internal mould of pedicle valve, destroyed by fire. 18*a–b*, Rubber casts of exterior and interior of brachial valves, F.4945B and F.4941. 19, Rubber cast of exterior, F.4940A. 20, Rubber cast of pedicle interior, F.4938E. 21, Rubber cast of pedicle exterior, F.4940B. 22, Rubber cast showing details of surface ornament, F.4938A, ×7. 23, Rubber cast of interior of pedicle valve, F.4938B, holotype. Note denticulation of hinge-line, delicate tracery of vascula genitalia, and large callus boss in delthyrium.



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valve variable septa which support the hinge-plate for greater or lesser distances. The same author (1955) has commented on and illustrated Permian specimens of *Wellerella*? with very long brachial median septa, and denticulate teeth and sockets. Further, the adductor scars of the brachial valve of the Permian specimens have a very unusual and distinctive arrangement. If these characters, which at present are not known in the genotype, are eventually proved to occur in it, they will provide further satisfactory means of distinguishing it from *Lissella*.

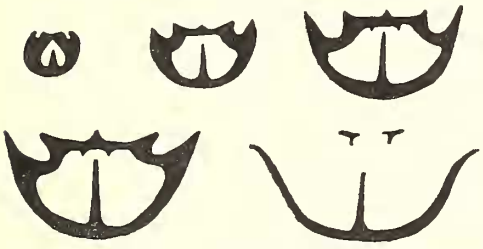
In *Leiorhynchus* the median septum of the brachial valve supports the hinge-plate in the umbo, and a small crural cavity is present. Further, the sockets are denticulate, and the adductor scars of the brachial valve are somewhat differently placed, and hence these specimens seem to belong to an entirely different stock.

Lissella booralensis sp. nov.

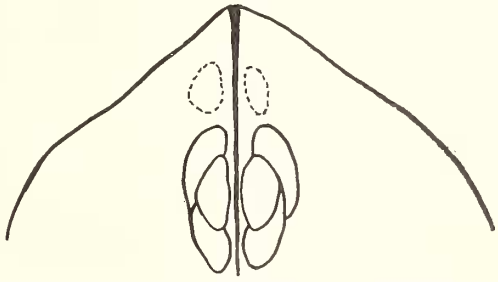
Plate 56, figs. 3–9

Holotype. F.5262; paratypes F.5263–F.5265 from the Booral Formation at 018859, and F.5268–F.5269 from the beds above the main *Levipustula* bed near 019840.

Description. Shell small, the largest one observed being only 16 mm. long; pedicle valve rather strongly convex near the umbo, but in general tends to be gently convex; postero-



TEXT-FIG. 8. Transverse sections across the brachial valve of *Lissella booralensis* gen. et sp. nov.; semi-diagrammatic, and reconstructed from sections of several internal moulds. ×3.



TEXT-FIG. 9. Camera lucida drawing of the muscle scars in the brachial valve of *Lissella booralensis* gen. et sp. nov. ×3.

lateral margins straight, and pass into a broadly rounded anterior; on anterior half to two-thirds of shell is a broad, rather shallow sinus, produced into a high tongue; umbonal region of lateral slopes smooth, but two or rarely three low rounded to subangular plicae (including the one bordering the sinus) developed anteriorly; median portion of sinus occupied by two, rarely one or three, rounded plicae not extending to umbo; deltidial plates narrow and short; foramen well rounded and relatively large.

Brachial valve strongly convex; lateral slopes steep; fold flat on top; plication in commissure high; usually three, sometimes two or four, rounded plicae on fold.

Pedicle valve with very delicate dental lamellae concave toward each other in transverse section and slightly divergent along the floor of the valve; lamellae extend one-sixth to one-quarter of total length of valve; arrangement of muscle scars unknown.

Brachial valve with a strong undivided hinge-plate with a minute perforation immediately in front of umbo; mid-line of hinge-plate with a low blunt ridge rising

gradually from the posterior and terminating much more abruptly anteriorly; crural bases strong, rather sharp, and situated on dorsal surface of hinge-plate; very strong median septum extends approximately half the length of the valve; septum never supports hinge-plate, though it comes very close to its dorsal face; near umbo septum very low and rounded but rapidly increases in height before reaching anterior edge of hinge-plate, maintains this height for some distance, and then gradually tapers to its anterior tip; muscle scars rarely visible, but on one specimen they are beautifully preserved (see text-fig. 9); socket plates strong; sockets not denticulate.

Remarks. This species occurs in considerable numbers on certain horizons of the Booral Formation but specimens are almost always grossly distorted. However, the sandy bed near 018859 has a large number of specimens well preserved as moulds. The specimens from the two types of sediment differ in that those from the mudstone usually have three to four plicae on the fold, and those from the sandstone have two to three.

The material is not well enough preserved to prepare accurate serial sections, but the internal moulds show the characters of the septum and hinge-plate very well.

Order CRYPTOSTOMATA Vine 1883
Family RHABDOMESIDAE Vine 1883
Genus RHOMBOPORA Meek 1872

Type species *R. lepidodendroides* Meek, Permian, America.

Remarks. These specimens are all preserved as moulds which are oval in cross-section, and at first it was thought that they had a similar cross-section to that of *Ottoseetaxis*. Mr. G. Fleming of the University of Queensland has shown me specimens from the

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EXPLANATION OF PLATE 56

All figures are of rubber casts and are at natural size unless otherwise stated.

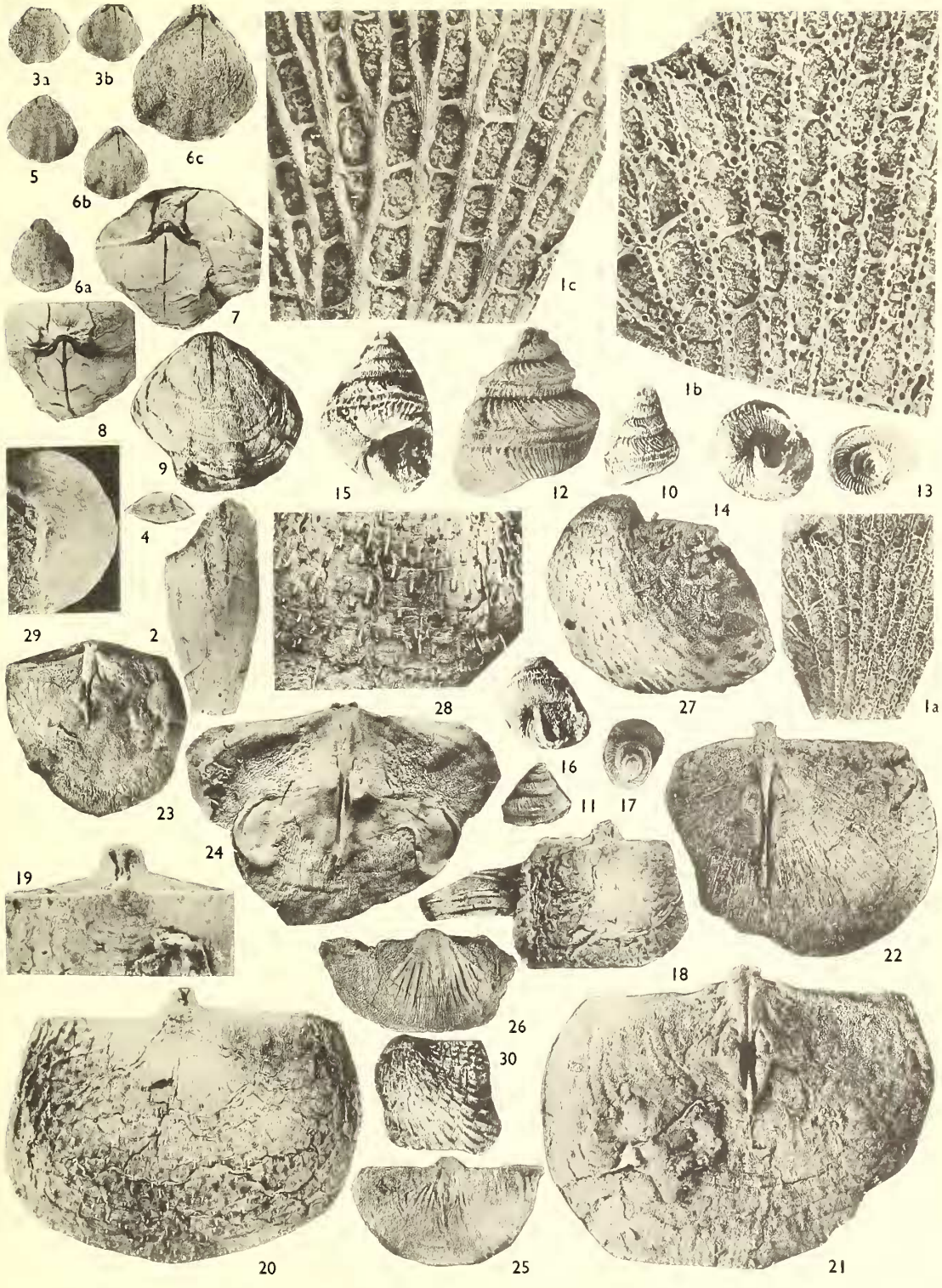
Fig. 1. *Fenestella stroudensis* sp. nov. 1*a*, Obverse surface, F.4704B, holotype, ×2·6. 1*b*, Same, ×6·3. 1*c*, Reverse surface, F.4704C, ×6.

Fig. 2. ? *Pentremites sp.* Isolated plate F.4714C, ×2.

Figs. 3–9. *Lissella booralensis* sp. nov. 3*a–b*, Ventral and dorsal views of internal mould, F.5264. 4, Anterior view of internal mould, F.5263. 5, Ventral view of internal mould, F.5265. 6*a–c*, Ventral and dorsal views of internal mould, F.5262, holotype; 6*c*, ×2. 7–8, Postero-dorsal views of internal moulds, F.5269, F.5268, ×2. Both show dental lamellae, dorsal median septum, and the separation of the septum from the hinge-plate. Fig. 8 also shows the pair of thickened ridges diverging from the septum beneath the hinge-plate. 9, Internal mould of brachial valve showing weakly impressed muscle scars; destroyed by fire, ×2.

Figs. 10–17. *Peruvispira kuttungensis* sp. nov. 10, 13–16, Views of several specimens destroyed by fire, all ×2. Note the parietal lips in 15 and 16. 11–12, 17, F.4935A, F.4935, and F.4937. Holotype F.4935, ×2.

Figs. 18–30. *Levipustula levis* Maxwell. 18–20, Exteriors of three brachial valves showing form of cardinal process and fine external spines. Note large spines from ears of pedicle valve in Fig. 18. F.4949A, F.4933A, ×4 and F.4954A, ×2. 21–24, Interiors of four brachial valves showing the variation in the area immediately in front of the cardinal process, and in the adductor scars. The brachial ridges in Fig. 24 are unusually well developed and the cardinal process is broken. F.4953, F.4957B, F.4952, and F.5304; all except Fig. 23 are ×2. 25–26, Internal moulds of pedicle valves viewed ventrally, F.4966 and F.4963. 27, 28, 30, Views of parts of external surfaces of pedicle valves, showing spine arrangements on body of valve and on ears. F.4977D, F.4957A both ×2, and Fig. 30 destroyed by fire. 29, Lateral view of internal mould of pedicle valve, F.4969.



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Neerkol Series with similar surface characters but which are preserved solid and have a circular cross-section.

The species is only doubtfully referred to *Rhombopora* since there is no differentiation of the acanthopores into a single megacanthopore at the distal edge of each aperture and micracanthopores elsewhere. It may possibly be allied to *Megacanthopora* Moore.

? *Rhombopora bifurcata* sp. nov.

Plate 60, figs. 5–7

Holotype. F.4706c; paratypes F.5249a–e and F.4714b from beds below the main *Levipustula* bed; F.4737c–e associated with *Alispirifer* bed above main *Levipustula* bed.

Description. Narrow zoarium of short branches almost uniform in width; probably circular in transverse section though all specimens squashed; zoarial width ranges from 0·8 to 1·5 mm.; no proximal portions of zoaria observed; the largest preserved specimen *c.* 20 mm. long consisting of a colony twice dividing symmetrically into two equal branches similar in width to the parent; apertures situated within elongate regularly arranged rhombic depressions in the surface; rhombs outlined by rather sharp ridges formed from edge of zooecial walls; length of rhombs varies from 0·5 to 0·9 mm. (though most lie between 0·6 and 0·8 mm.) and width from 0·2 to 0·3 mm.; aperture sometimes clearly defined by a distinct break of slope, but often vestibule merges imperceptibly into inner wall; apertures vary considerably in outline, some being simply oval, a few tending to be circular, and others elongate and pointed distally but rounded proximately; apertural lengths, where measurable, vary between 0·15 and 0·25 mm., and widths between 0·07 and 0·15 mm.; acanthopores (megacanthopores) common, giving rise to stout distally directed spines, and placed one at the distal end of each rhomb making four around each aperture, or frequently two near the end of each rhomb and odd ones along the sides making up to eight around some apertures; immature portions of zooecia apparently arise from an axis, have thin walls, and appear to be irregularly depressed in outline in transverse section; as they approach maturity, zooecia increase gradually in diameter and curve rather sharply to mature region where they decrease slightly in width to the aperture; no diaphragms or hemisepta; skeletal material in mature region dense; apparently no vesicular tissue present anywhere in zoarium.

Remarks. Most of the specimens are preserved as moulds, and no material suitable for preparing thin sections has been discovered. The internal details have been observed either in the moulds or on polished surfaces of partly decomposed specimens. I know of no species with which to compare it.

Family FENESTELLIDAE King 1850
Genus FENESTELLA Lonsdale 1839

Type species *F. antiqua* Lonsdale, Silurian, England.

Fenestella cerva sp. nov.

Plate 59, figs. 1*a–c*

Holotype. F.4718; paratypes F.4705g–h and F.4709a, all from below the main *Levipustula* bed near 019840.

Description. Zoarium with 5½–6 fenestrules and ten to twelve branches in 10 mm.; branching frequent; obverse surface of branches with high sharply defined keel occupying up to almost half width of branch; apertures situated in a distinct shallow depression on either side of keel; nodes high, oval at base, spaced at intervals of 0·6–1·2 mm. and numbering twelve to eighteen per 10 mm.; whole of obverse surface, including keel, with very delicate striae on which are very fine pustules of variable strength; reverse surface of branches well rounded and finely striate; apertures exsert, surrounded by peristomes usually almost circular in outline and often slightly higher proximally than distally; apertural diameter 0·12–0·18 mm., and centres of apertures usually 0·35–0·50 mm. apart with some up to 0·60 mm.; change from two to three rows of apertures takes place immediately prior to branching; usually four to five apertures per fenestrule, rarely three; dissepiments short—0·1–0·25 mm., either slightly above or below the level of the branches on obverse surface, and delicately striate; on reverse surface dissepiments slightly depressed; junction between branches and dissepiments angular making for sub-rectangular fenestrules, though some are slightly oval; fenestrule length 1·3–2·2 mm., most being 1·5–2·0 mm., and width 0·4–0·8 mm., zooecia irregularly subpentagonal in outline on basal plate.

Remarks. This species is not unlike *F. malchi* (Crockford) in many respects, but it can be distinguished from that form by its slightly longer fenestrules, sharply defined carina, and probably also by the peristomes. The latter are not mentioned in Crockford's original description. According to the text (Crockford 1948, p. 422) *F. malchi* has four, rarely three, apertures per fenestrule, but the figure of the type shows four to five. Should the former be accurate, then this character is another basis of distinction from *F. cerva.*

Fenestella stellaris sp. nov.

Plate 58, figs. 4*a–d*

Holotype. F.4716A–B; paratype F.4717; both from below the main *Levipustula* bed near 019840.

Description. Rather rapidly branching; ten to twelve fenestrules and fifteen to eighteen branches in 10 mm.; obverse surface of branches broadly rounded, reverse surface much more sharply rounded; branches 0·20–0·35 mm. wide at middle of fenestrules; number of rows of apertures increases to three only 1 mm. or so prior to bifurcation; usually two, occasionally three apertures per fenestrule; apertures strongly exsert, surrounded by high peristomes, from which arise eight to nine projections which continue down inside the peristome as septum-like plates; at base of these plates, aperture crossed by

EXPLANATION OF PLATE 57

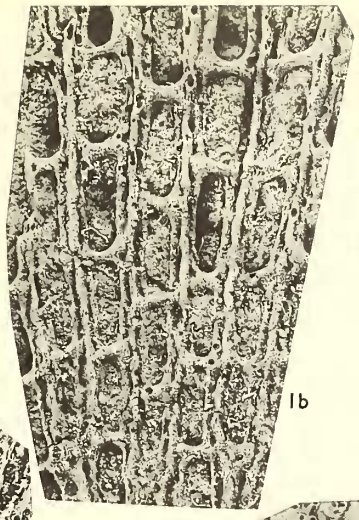
All figures are of rubber casts.

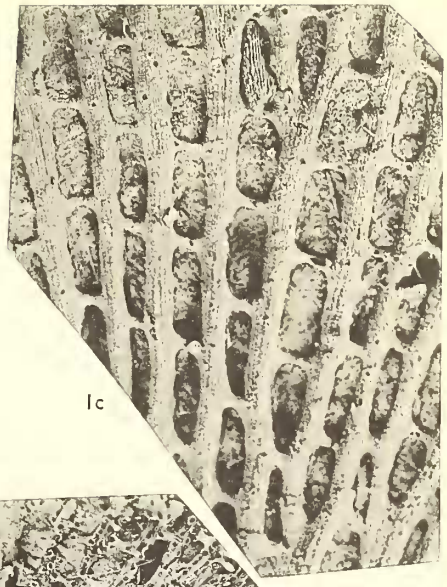
Fig. 1. *Fenestella rectangularis* (Crockford). 1*a*, Obverse surface, F.4709B–C, ×4·6. 1*b*, Enlargement of same, ×10. 1*c*, Reverse surface of same, ×10. Bubbles in the rubber along the keel in 1*a–b* mark the position of the nodes, and in 1*c* the positions of small pustules shown elsewhere as slightly lighter coloured patches.

Fig. 2. ? *Fenestella altinodosa* sp. nov. 2*a*, Obverse surface, F.4708A, holotype, ×5. The white spots on the branches mark the positions of the large nodes. 2*b*, Enlargement of same, ×9.

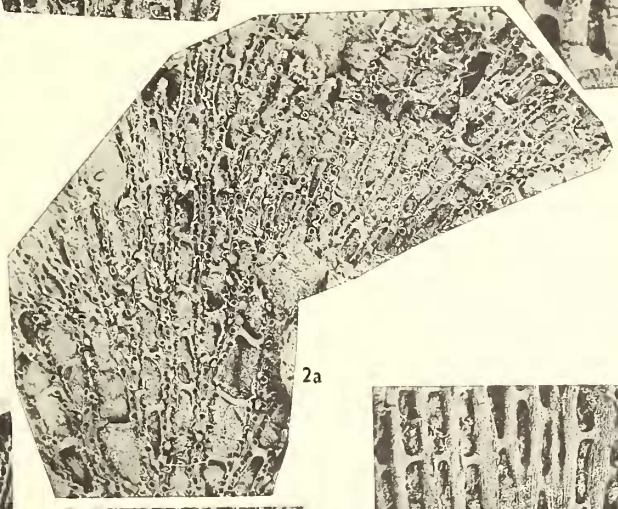
Fig. 3. *Fenestella anodosa* sp. nov. 3*a*, Obverse surface, F.4700B–C, holotype, ×4·5. 3*b*, Enlargement of another part of same zoarium, ×10. 3*c*, Reverse surface of same, ×4·5.


1a


1b


1c


2b


2a


3a


3b


3c

CAMPBELL, Carboniferous Polyzoa

axially perforated, arched, diaphragm-like plate; diameter of apertures 0·12-0·16 mm.; centres of adjacent apertures 0·3 to 0·45 mm. apart; no median keel; large nodes directed distally and irregularly arranged on obverse surface—never in a median row; numerous subrounded depressed areas irregularly scattered over surface between apertures; apertures never open into depressed areas; fenestrules oval to subrectangular, 0·5–0·8 mm. long and 0·3–0·4 mm. wide; dissepiments 0·2–0·25 mm. long; striae on reverse surface weak or absent, but surface with large distally directed spines of irregular size and distribution, often situated on the branches at their junction with the dissepiments.

Remarks. The nodes on the obverse surface lie at an unusually low angle to the surface, and their arrangement is highly irregular. In some places they are less than 0·5 mm. apart, and elsewhere 4 or 5 mm. apart. Occasionally they occur in groups of three or four.

It differs from all other Carboniferous species in its node arrangement and in the depressed areas on its surface into which the apertures do not open.

Fenestella anodosa sp. nov.

Plate 57, figs. 3*a–c*

Holotype. F.4700B–C; paratype F.4701; both from above the main *Levipustula* bed near 019840.

Description. Zoarium with $4\frac{1}{2}$–$5\frac{1}{2}$ fenestrules and about twelve branches per 10 mm.; branches normally 0·3–0·5 mm. wide, expanding to 0·9 mm. prior to bifurcation; keel of variable height, but always prominent, and in places tending to be bladed; no nodes; branches moderately furrowed on each side of keel; reverse surface broadly rounded, striate and without nodes; apertures 0·16–0·22 mm. in diameter and 0·40–0·52 mm. apart; peristomes strong; on some parts of the branches are low sharp transverse ridges joining the keel to the fenestrules; these ridges variably spaced, but as little as about 0·25 mm. apart in some areas and completely absent in others; change from two to three rows of zooecia takes place from 0·5–3·0 mm. prior to bifurcation, there being two strong keels separating the three rows of apertures; four, rarely five, apertures per fenestrule; dissepiments 0·1–0·2 mm. long, and on the general level of the branches on both the obverse and reverse surfaces; fenestrules subrectangular to suboval, 1·5–2·1 mm. long and 0·4–0·6 mm. wide; zooecia subpentagonal on the basal plate.

Remarks. The two main distinguishing features of this species are the sharp keel without nodes, and the sharp transverse ridges across the branches. These latter give a very knobbled appearance of distinctive type to the moulds. *F. cincta* (Crockford) has similar ridges on the obverse face, but these apparently always surround an aperture, whereas on *F. anodosa* they isolate depressed areas both around and between the apertures. *F. cincta* also has a very much coarser mesh.

Fenestella crockfordae sp. nov.

Plate 59, figs. 2*a–b*

Holotype. F.4699A–B; paratypes F.4698 and F.4697A–B; all from above the main *Levipustula* bed near 019840.

Description. Zoarium with $3\frac{1}{2}$–$4\frac{1}{2}$ fenestrules and ten to twelve branches in 10 mm.; obverse surface of branches with high, broad, usually well-rounded keel; nodes high,

oval at base, numbering eight to eleven per 10 mm., and situated 1·0–1·5 mm. apart; strong depression along branches on either side of keel; whole obverse surface, including dissepiments with delicate striae, carrying very fine pustules; reverse surface well-rounded striate, and without nodes; apertures circular to slightly oval and surrounded by strong peristomes; apertural diameters 0·16–0·20 mm., and centres of adjacent apertures 0·35–0·55 mm. apart; many apertures covered by a centrally perforate plate at base of peristome; change from two to three rows of apertures takes place immediately before branching; four to six apertures per fenestrule; fenestrules subrectangular in shape ranging in length from 2·0–3·2 mm. (most 2·2–2·6 mm.), and in width from 0·5–0·8 mm.; zooecia irregularly subpentagonal on the basal plate.

Remarks. The mesh structure clearly separates this species from all others so far described from the Australian Carboniferous.

Fenestella stroudensis sp. nov.

Plate 56, figs. 1*a–c*

Holotype. F.4704A–B; paratype F.4703, both from below the main *Levipustula* bed near 019840.

Description. Zoarium with $5\frac{1}{2}$ fenestrules and ten to twelve branches in 10 mm.; obverse surface with weak, blunt keel, and sometimes keel virtually absent; no nodes; no furrow developed lateral to keel; whole surface with strong wavy striae; reverse surface of branches broadly rounded, strongly striate, and without nodes; apertures circular to slightly oval, 0·16–0·20 mm. in diameter, and with their centres 0·30–0·50 mm. apart; peristomes thin and moderately high; change from two to three rows of apertures up to 3 mm. prior to bifurcation; usually four, rarely five, apertures per fenestrule; dissepiments 0·12–0·16 mm. long, generally more or less on a level with the branches on the obverse surface, slightly raised or slightly depressed on the reverse; fenestrules subrectangular to suboval; fenestrules 1·5–2·0 mm. long and 0·4–0·8 mm. wide, occasional ones wider.

Remarks. The low keel and the absence of nodes separates this species from other members of the fauna with similar mesh dimensions.

? *Fenestella altinodosa* sp. nov.

Plate 57, figs. 2*a–b*

Holotype. F.4708A, from the Booral Formation, below the main *Levipustula* bed near 019840.

Description. Rather coarse mesh, with six to seven fenestrules and about twelve branches in 10 mm.; fenestrules 1·3–1·8 mm. long and 0·4–0·6 mm. wide; branches 0·4–0·5 mm.

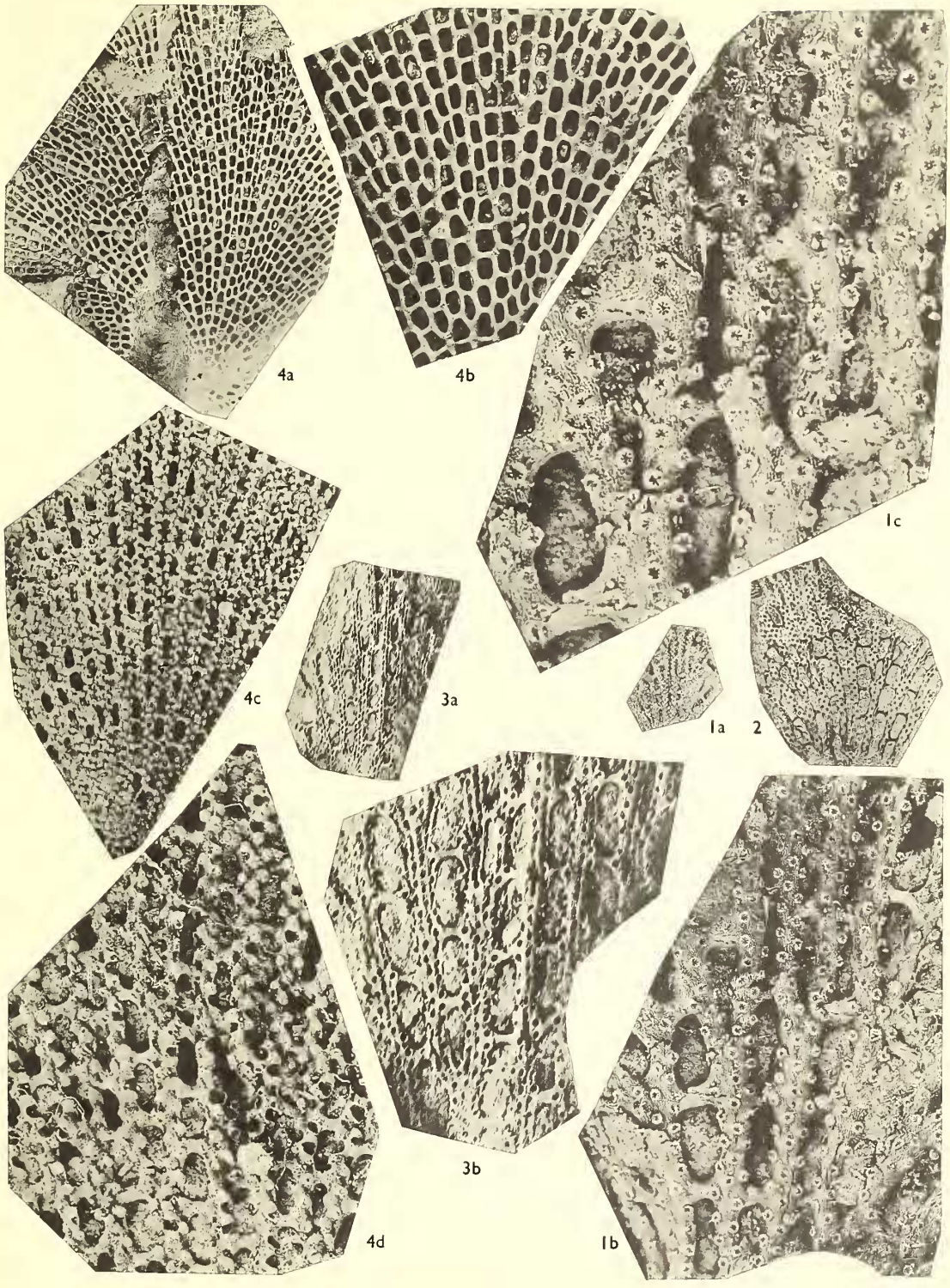
EXPLANATION OF PLATE 58

All figures of rubber casts except Fig. 2.

Figs. 1–2. *Polypora septata* sp. nov. 1*a–c*, Obverse surface of holotype, F.4708D, ×1·5, 10, and 20 respectively. 2, Mould of obverse surface of F.4734D, ×2·5.

Fig. 3. *Polypora sp.* 3*a–b*, Obverse surface of specimen destroyed by fire, ×1·9 and 5 approximately.

Fig. 4. *Fenestella stellaris* sp. nov. 4*a–b*, Reverse surface of holotype, F.4716A–B, ×2 and 4. Note numerous rounded nodes. 4*c–d*, Obverse surface of same, ×4·7 and 10·5. Note large depressions in surface of branch between apertures.



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wide, expanding to 1·0 mm. prior to bifurcation; edges of branches on obverse face forming a sharp rim to the fenestrules; surface of branches with strong raised ridges usually six in number, but increasing to twelve prior to bifurcation; sometimes median ridge slightly stronger than those on either side; ridges very finely pustulose; dissepiments arched, raised well above the general level of the surface of the branches and carrying lateral extensions of the ridges from the branches; nodes very large, circular to slightly oval at the base where the diameter is 0·12–0·20 mm., and fluted; nodes somewhat irregularly spaced at nine to fifteen per 10 mm., and not always situated along the mid-line; apertures with strong peristomes, slightly oval in outline and 0·20–0·24 mm. in longitudinal diameter; increase from two to three rows of apertures takes place from 2–4 mm. prior to branching; distance between successive apertures is 0·40–0·50 mm.; usually four, occasionally three apertures per fenestrule.

Remarks. The high nodes clearly distinguish this species. There is no trace of a meshwork such as that characteristic of *Hemitrypa*, and so far as can be determined at present the nodes terminate bluntly. However, the possibility that there are expanded terminations to the nodes in places has not been ruled out.

Other odd features of the species are the absence of a clearly defined median carina, the development of the nodes from any part of the obverse surface, and the increase from two to three rows of apertures on the branches well before bifurcation. Perhaps it would be equally well placed in *Polypora*.

Fenestella rectangularis (Crockford)

Plate 57, figs. 1*a–c*

1948 *Fenestrellina rectangularis* Crockford, p. 425, fig. 7.

Material. F.4705D–F, F.4709B–C, all from the Booral Formation, below the main *Levipustula* bed, near 019840.

Remarks. This species has not previously been recorded from New South Wales, though it is common in Queensland. The specimens agree very well with the original description, but their range of variation is slightly wider in some characters. The fenestrules are 0·9–1·4 mm. long; the apertures 0·1–0·18 mm. in diameter; the nodes 0·6–0·9 mm. apart, and they number fourteen to eighteen per mm. Features not previously noted are the presence of numerous nodes of irregular size and spacing on the reverse surface; the presence of a shallow furrow in which the apertures are situated, on either side of the keel; the keel is variable in height and width, but is always well rounded, and the nodes vary in size to a remarkable degree even on the one individual; the whole of the obverse face including the keel is very delicately striate and pustulose; the zooecia are subpentagonal on the basal plate, but are also inclined to be pointed proximally to the inclination of the cells to the line of the branches; the change from two to three rows of zooecia takes place immediately prior to branching.

Fenestella sp. cf. *rectangularis* (Crockford)

Material. F.4738A–D, F.4740A–B, F.4741A–B, F.4743A–B, all from the Isaacs Formation near 987823.

Remarks. This species has similar mesh dimensions, zooecial and node spacing, and keel structure to *F. rectangularis*, but differs in having no nodes on the reverse surface of the

branches, and in the development of a double keel and three rows of zooecia on the branches up to 0·5 mm. prior to bifurcation.

Fenestella malchi (Crockford)

1948 *Fenestrellina malchi* Crockford, p. 422, fig. 4.

Material. F.4739 from the Isaacs Formation near 987823.

Remarks. This specimen shows all of the characters of this species except that the nodes are slightly closer together than normal.

Fenestella cf. *cincta* (Crockford)

Material. F.4697C, F.4700A, F.4715E, F.4719, F.4726C–D, from the Booral Formation above the main *Levipustula* bed near 019840.

Remarks. These specimens have the dimensions and fenestrule shape of the types. The keel, however, is very variable in height, being broad and rounded to rather high and sharp though it is never clearly defined. The edges of the branches are sometimes slightly raised and sharp, so that the zone occupied by the apertures on either side of the keel is slightly excavate. Other points of distinction from the types are the slight raising of the dissepiments above the general level of the branches on both surfaces, and the infrequency with which the depressed areas bounded by thin sharp ridges occur on the obverse face.

A feature not previously observed is that no increase from two to three rows of zooecia takes place prior to bifurcation of the branches.

Fenestella osbornei (Crockford)

Plate 59, fig. 3

1948 *Fenestrellina osbornei* Crockford, p. 424, fig. 5.

Material. Numerous specimens from throughout the fossiliferous section except for the *Liriplica* bed, near 019840.

Remarks. This is the most common species of *Fenestella* in the fauna. Its type locality is in the Booral Formation near where the bulk of the present collection has been obtained. Its variability is much greater than indicated by Crockford, and apparently it is one of the species in which the mesh structure changes during the growth of the colony. On one individual, fenestrule length changes from 0·55–0·7 mm. at the early

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EXPLANATION OF PLATE 59

All figures except Fig. 4 are of rubber casts.

Fig. 1. *Fenestella cerva* sp. nov. 1*a*, Part of the obverse surface of F.4718, holotype, ×2. 1*b–c*, Part of surface of same, ×8.

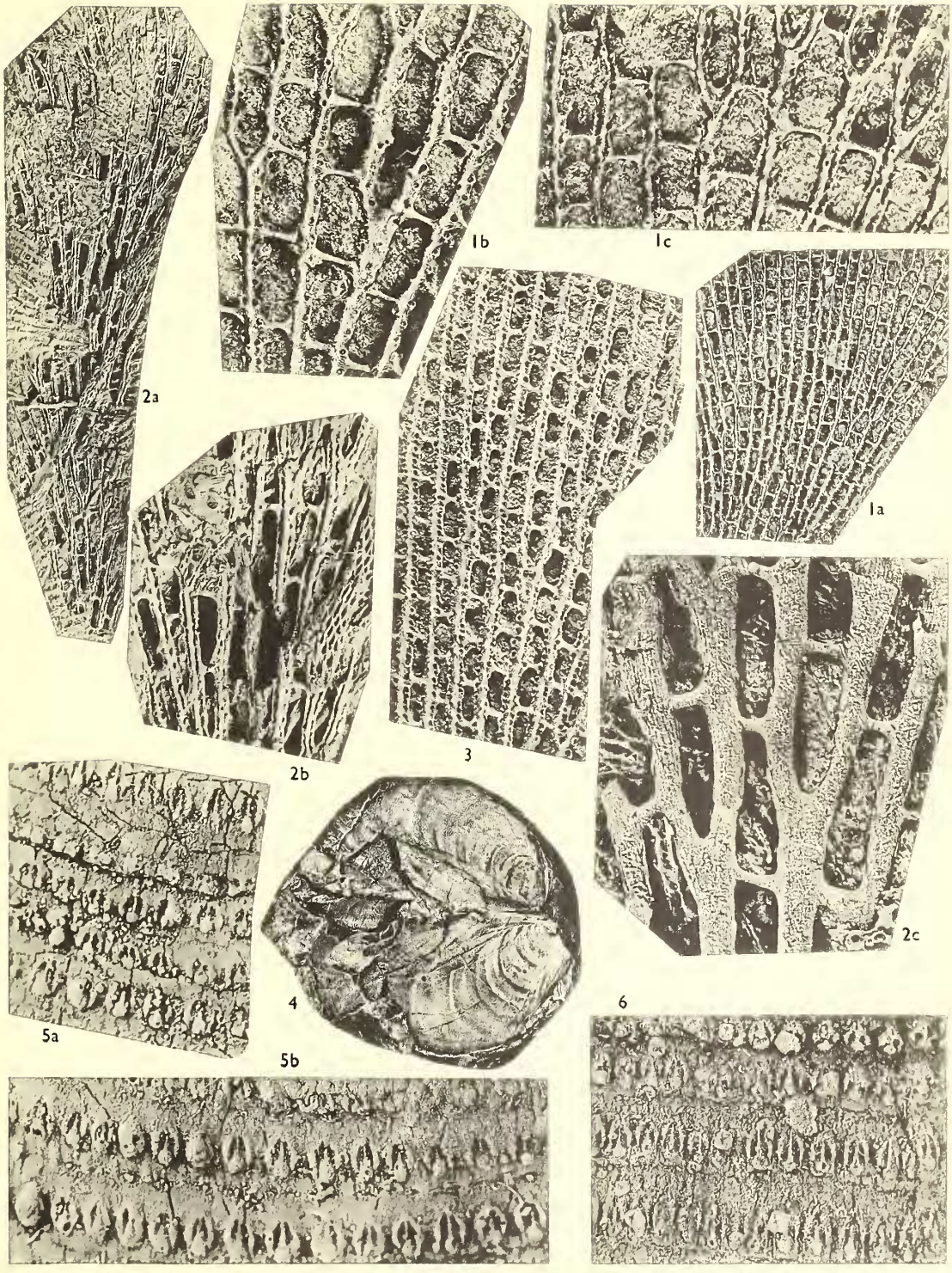
Fig. 2. *Fenestella crockfordae* sp. nov. 2*a*, Obverse surface of F.4699A–B, holotype, ×2. 2*b*, Part of surface of same, ×4. 2*c*, Reverse surface of same, ×10. Note fragment of *R. bifurcata* in 2*a–b*.

Fig. 3. *Fenestella osbornei* (Crockford). Part of obverse surface of well-preserved specimen, F.4702, ×7 approximately.

Fig. 4. *Posidonia sp.* Internal mould of badly crushed specimen, F.4039, ×1.

Fig. 5. *Phricodothyris immensa* sp. nov. 5*a–b*, Detail of spine bases, F.4914G and F.4916A, ×12.

Fig. 6. *Phricodothyris booralensis* Campbell. Detail of spine bases, F.4902B, ×12.



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